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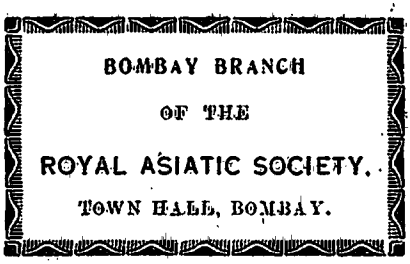

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REPORTS AND PAPERS

ON

BOTANY.

CONSISTING OF

I.—MOHL ON THE STRUCTURE OF THE PALM-STEM.

II.—NÄGELI ON VEGETABLE CELLS.

III.—NÄGELI ON THE UTRICULAR STRUCTURES IN THE CONTENTS OF CELLS.

IV.—LINK'S REPORT ON PHYSIOLOGICAL BOTANY FOR 1844-45.

V.—GRISEBACH'S REPORT ON GEOGRAPHICAL BOTANY FOR 1844.

VI.—GRISEBACH'S REPORT ON GEOGRAPHICAL AND SYSTEMATIC BOTANY FOR 1845.

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EDITED BY

ARTHUR HENFREY, F.L.S.

&c. &c.

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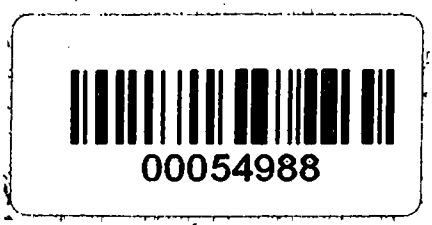

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CONTENTS.

ON THE STRUCTURE OF THE PALM-STEM.

By Prof. H. von Mohl.

	PAGE
Introduction	3
On Palm-Stems	5
Form of the Palm-Stem	ib.
Course of the Vascular Bundles in the Stem . .	7
Cellular Tissue of the Palm-Stem . . .	10
Structure of the Vascular Bundle . . .	15
Modifications of the Structure of the Vascular Bundle in various Palm-Stems	19
Of the Structure of the particular Anatomical Systems of the Vascular Bundle	20
Comparison of the Palm-stem with the stems of other Monocotyledons	30
Comparison of the Vascular Bundle of the Palms with that of the Dicotyledons	36
Comparison of the Palm-stem with the Stem of Dicotyledons	39
On the Root of the Palms	45
Form of the Root	ib.
Anatomical Examination of the Root . . .	46
Appendix	51

ON THE NUCLEI, FORMATION, AND GROWTH OF VEGETABLE CELLS. By Prof. C. Nägeli.

PART II.

		PAGE
IV.	Free Cell-formation	95
	a. Without Visible Nucleus	ib.
	b. With a parietal Nucleus	103
	c. Of free Cell-formation as a general Law	111
V.	On Cell-formation in general	123
VI.	On the Growth of Cells	143

ON THE UTRICULAR STRUCTURES IN THE CONTENTS OF CELLS. By Prof. C. Nägeli.

	Introductory	161
1.	Nuclear Utricles, Nuclei	165
2.	Spermatic Utricles	171
3.	Nucleoli	172
4.	Mucilage- (Protoplasm-) utricles	173
5.	Proliferous Utricles	175
6.	Colour-utricles	176
7.	Starch-utricles, Starch-granules	183
8.	General Retrospect	188

REPORT ON PHYSIOLOGICAL BOTANY for 1844 and 1845. By Prof. Link.

	General Observations	193
I.	Internal Structure of Plants	221
II.	Stem and Root	249
III.	Root, Tubers, Prickles, Tendrils, Glands, Stomata	264
IV.	Leaves	270
V.	Flowers, Fructification	282
VI.	Fruit, Seeds, Germination	290
VII.	Individual Orders and Genera of the Phanerogamia in Reference to Physiology	296
VIII.	Ferns, Mosses, Lichens, Algæ, Fungi	304
IX.	Monstrosities	312

REPORT ON GEOGRAPHICAL BOTANY FOR 1844.

By Prof. Grisebach.

PAGE

Introductory 317
I. Europe 323
II. Asia 349
III. Africa 377
IV. Islands of the Atlantic Ocean 388
V. America 390
VI. Australia and South Sea Islands 407

REPORT ON GEOGRAPHICAL AND SYSTEMATIC BOTANY FOR 1845. By Prof. Grisebach.

A. Botanical Geography 418
I. Europe 423
II. Asia 455
III. Africa 457
IV. America 458
V. Australia and South Sea Islands 469
B. Systematic Botany 474

Explanation of the Plates.
Mohl on the Palm-Stem 495
Nägeli on Vegetable Cells . . . . . ib.

Index to the Physiological Report 503
— Geographical Botany 507
— Systematic Botany 512

ON THE

STRUCTURE OF THE PALM-STEM.

BY HUGO VON MOHL.

(The Treatise 'de Structura Palmarum' contained in Martius's 'Genera et Species Palmarum.')

TRANSLATED, WITH THE APPENDIX,

(From the German version, published by the Author, in his 'Vermischte Schriften botanischen Inhalts'—Tübingen, 1845,)

BY ARTHUR HENFREY, F.L.S. ETC.

STRUCTURE OF THE PALM-STEM.

INTRODUCTION.

A minute anatomical examination of the Palms is of especial importance in regard to the anatomy and physiology of plants, because the characters of the Monocotyledons are most clearly exhibited in them, and they therefore afford the most favorable means of acquiring satisfactory ideas of the structure and growth of this great class of plants. As the earlier phytotomists had devoted but little care to the examination of Palm-stems,* these suddenly acquired very great importance when Daubenton, in the examination of the Date-palm, believed that he found the vascular bundles proceeding to the young leaves, becoming developed in the interior of the stem, surrounded by the vascular bundles running to the older leaves. This proposition, forming an epoch in the history of Phytotomy, first appeared in its full importance when Desfontaines† showed that, not only in the Date-palm, but in Monocotyledons generally, the wood has the form of scattered vascular bundles, and that the vascular bundles which run to the leaves come from the centre of the stem. This

* Vide Grew's Examination of Calamus, Anat. of Plants, p. 104.

† Mém. sur l'Organisat. d. Monoc. (Mém. de l'Institut National, t. i, 478). According to a brief notice published by Mirbel (Comptes Rendus, 12 Juin, 1843), the first discovery belongs to Desfontaines, he having already, in his 'Travels in Algiers,' expressed in a few words the idea which lies at the foundation of his system.

discovery necessarily excited the greatest attention; the doctrine, that the vascular bundles of the Monocotyledons originate in the centre of the stem, and press the older bundles outward; that this process continues until the older and solidified vascular bundles form a layer at the circumference of the stem sufficiently firm and hard to resist the pressure of the younger; that thereupon all further increase of thickness of the stem must cease, and that from this results the columnar form of the stem—this doctrine appeared to explain the peculiarities of the growth of Monocotyledons in a manner so simple and satisfactory, that it not only passed into all text-books, but was even used by De Candolle for the systematic division of vascular plants into Endogens and Exogens. The observations of Dupetit-Thouars* showed, indeed, that the stem may grow to an unlimited thickness in many Monocotyledons; they were not, however, any more than the later observations of Mirbel, sufficient to shake the belief in the correctness of Desfontaines' doctrine, and only gave occasion for the assumption that in some Monocotyledons a second peripherical growth occurs, in addition to the central vegetation. One voice, alone, but therefore the more important, declared against the theory of the central growth of Monocotyledons.† Moldenhawer stated that in the stem of *Phœnix dactylifera* a line of division occurs, on both the outside and inside of which liber-bundles are equally developed; that around those in the latter situation, spiral vessels are produced subsequently to their first formation, and they thus become ligneous bundles; and that of these ligneous bundles, the inner run to the older leaves, and the outer to the younger; that consequently, in other words, the date-palm has a peripherical growth. Like so many other admirable remarks of this exact observer, this proposition was so completely neglected by other vegetable anatomists, that not one thought it even worth the trouble of mentioning.

* Premier Essai sur la Végétation.
† Beiträge zur Anatom. d. Pflanzen, 53.

ON PALM-STEMS.

Form of the Palm-stem.

The organization of the Stem of Palms undoubtedly exhibits common characters throughout all species: it is simple (except in *Hyphæne*), almost cylindrical, generally upright, encircled by the scars of the leaves which surround the stem, but without true nodes; fixed to the earth by slender fibrous roots; having at the apex a tuft of leaves, in the axils of which stand the spadices. The internal structure is, generally speaking, as follows: the groundwork of the whole stem is an uniform, lax parenchyma, in which lie, scattered irregularly, slender vascular bundles, running apparently parallel with the axis of the stem; those lying nearest to the circumference of the stem are mostly thicker, of a more woody consistence, and placed closer together than those situated in the interior; from this circumstance, the stem often possesses very considerable solidity toward the periphery.

For the convenience of anatomical description, I divide Palm-stems into some subdivisions, which, however, do not correspond to the systematic subdivisions based on the modifications of the structure of the flowers and fruit.

1. The *Cane*-like (*Geonoma*-like) palm-stem, *Caudex arundinaceus*, is thin, slender, upright, with the nodes tolerably near together, the internodes obconical, the epidermis smooth, shining, and not decaying from the action of the atmosphere. These stems are moderately strong, the parenchyma is simple and close, the fibres lying in the middle of the stem softer, those at the circumference often pretty hard, the liber-like layer weak. At first sight, these stems bear much resemblance to the stems of Grasses, especially of bamboo, to which the yellow colour acquired on drying, and the obconical form of the internodes, which give the stem an articulated aspect, much contribute; they are, however, easily distinguished from the culms and subterraneous stems of Grasses, by the absence of a central cavity, and by the circumstance that the vascular bundles do not form any reticularly branched interlacement at the nodes. This stem occurs in most species of *Geonoma*, many species of *Bactris*, in *Hyospathe*, *Chamædorhea*; similar forms, but

constituting the transitions to the other forms of stems, are found in *Desmoneus, Rhapis flabelliformis*, and *Corypha frigida.*

2. The *Calamoid* stem (*Caudex calamosus*) resembles the cane-like, but is distinguished by the extraordinary length. The internodes are from two to six feet long, thin, apparently cylindrical, but equally obconical; the surface smooth, shining as if varnished; of a stony hardness. The substance is not firmer at the periphery than in the middle; the vascular bundles are distributed almost uniformly throughout the whole stem; the woody mass is moderately hard, exceedingly elastic, and tough; the external fibrous layer is very thin; the stony, hard epidermis splits off in scale-like pieces when the stem is bent. This form occurs only in *Calamus;* the transition to the cane-like stem is through *Desmoneus.*

3. The *Cylindrical* (*Mauritia*-like) stem is remarkable for its beautifully regular uniformity and smooth, round form. The internodes are pretty long and cylindrical; the leaf-scars are narrow and do not form knot-like projections; the rind thin, not much affected by the action of the atmosphere, often clothed with spines. The internal structure is very strongly marked; almost the whole mass consists of a weak, lax, pith-like parenchyma, in which lie vascular bundles of herbaceous softness. Firm woody vascular bundles are only found at the periphery in a narrow circle; but on account of their frequently considerable thickness and hardness, they form an almost impenetrable layer. The external fibrous layer is mostly very thin. This form occurs in *Mauritia* (*armata, vinifera*), *Œnocarpus* (*minor*, &c.), *Kunthia* (*montana*), *Astrocaryum* (*vulgare*, &c.)

4. *Cocos*-like stem (*Caudex cocoides*). This is thick, and somewhat irregularly knotted from the closely approximated, broad leaf-scars, and frequently shaggy with the vascular bundles of the fallen leaves and withered leaf-sheaths; often very tall. The vascular bundles are distributed almost uniformly throughout the whole mass; those situated near the periphery are merely a little more closely approximated than the internal, and are rather thinner than thicker than the latter. The liber-like fibrous layer is very thick; the rind thick, irregularly torn, and weathered. The ligneous bundles are sometimes rather soft, as in *Corypha cerifera*, but also sometimes very hard, as in *Cocos coronata.* On account of the uniform distribution of the vascular bundles, the stem is nearly as hard in the middle as in the outer part, and on account of the great number of bundles, it presents considerable solidity. This form of stem occurs in *Cocos, Leopoldinia, Syagrus, Elais, Corypha; Rhapis flabelliformis* and *Lepidocaryum gracile* form the transition to the cane-like stems.

5. Stemless Palms. In some the length is so small that the plants seem to be stemless. Two varieties occur. In the first the stem is abbreviated, like a bulb. This is not peculiar to any special genus, but occurs in individual species of the most varied genera, e. g. in *Geonoma acaulis, macrostachys; Astrocaryum acaule, campestre; Diplothemium maritimum, campestre, littorale.*

Isolated species occur with stems sometimes very much abbreviated, and at other times of tolerable length, e. g. *Attalea compta*. The second variety occurs in *Sabal;* here the stem forms a short, creeping rhizome, of a most remarkable form, its leafy apex lying on the ground, while the hinder extremity is lifted up by the roots, and projects above the ground.

Note.—I had no specimens of this fifth form to examine; the following remarks relate, therefore, only to the first four forms of stems mentioned.

Course of the Vascular Bundles in the Stem.

Before I proceed to the microscopic anatomical description of the stem, it will be necessary to describe the course of the vascular bundles. It is known that these do not lie in concentric circles, but are scattered without definite arrangement throughout the stem. This difference of the Palms from Dicotyledonous trees is so striking, that even in ancient times it was regarded as a characteristic peculiarity of Palms.* The course of the vascular bundle is best traced in stems where the parenchyma has lost its firmness by decomposition; in these the individual bundles may with very little trouble be extricated from a stem split longitudinally. Stems with a white pith-like centre are also very well adapted to this investigation. When, in such a stem, e. g. *Kunthia montana*, a vascular bundle is traced from the point of insertion of the leaf backward, it is found that it runs in a curve (the convexity upward,) to the centre of the stem, then in the neighbourhood of the centre runs down a certain extent deep in the stem, but soon again loses the direction parallel to the axis of the stem, gradually (since at the same time it is always running down the stem) again approaching the surface, till it lies beneath the rind, and there passes down the stem beneath this.

Obs. I have here described the course of the vascular bundle in the direction from above downward, because I usually traced them in this

* Theophrast., Hist. Plant., lib. i, cap. ix.

direction in the stem; but it must not be hence inferred that the vascular bundle of Palms is perfected in this direction in its formation; and in the following pages I shall, according as it may be more conveniently stated, follow the vascular bundle, in the anatomical description, sometimes from above downward, and sometimes in the opposite direction.

The course of the vascular bundle is the same in all Palms, and the only distinctions which present themselves are a difference of aspect at different points of the course of the vascular bundle in different species.

In those species, for instance, which, like *Kunthia montana* and *Mauritia aculeata*, possess firm woody vascular bundles only at the periphery of the stem, with a centre composed of soft, herbaceous substance, we find that all the bundles are thin, soft, and herbaceous from the point where they enter the leaf, downward to the centre of the stem, and from here outwards to the point where they approach the outer hard, woody layer, and that as they proceed downward in their course in that layer, they gradually become denser, and of a firm ligneous consistence. When the vascular bundles have reached the external part of this layer, and become situated beneath the rind, their thickness is diminished, but not their firmness and hardness; the latter peculiarity, however, is less remarkable, on account of their smaller diameter. They run in this manner, in the form of slender fibres, between the firm, woody layer and the rind, to the base of the stem, or terminate, after a course of variable length, in other vascular bundles, becoming blended with them. As all the vascular bundles have a similar course, and the portion running in the middle of the stem is soft and herbaceous in all, the medulla-like softness of the centre of the stems is easily explained. It is also clear that the hardness of the outer layer of the stem results from the thickness and solidity acquired by the collective vascular bundles during their course through this outer layer; further, that the liber-like fibrous layer under the rind is formed by the lower extremities of the vascular bundles, and is not to be compared with the liber of Dicotyledons.

The vascular bundles of the *Cocos*- and *Calamus*-like stems are distinguished by their not exhibiting that herbaceous softness in their course from the leaf to the centre, and from this to the outer layer of the stem, for they also appear thick and woody here, although in a less degree than in the outer layers. With regard to the inferior portion of the vascular bundle, two varieties are met with in the *Cocos*-like stem: it either passes, as in *Kunthia*, into a thin fibre, and the external fibrous layer of the stem is then thin, as in the rest of the forms, or the vascular bundle divides, at its exit from the hard layer, into several smaller bundles, which, after a short course, lose themselves in a multitude of fine fibres; the fibrous layer is then thick, as, for instance, in *Cocos nucifera*, *coronata*, &c.

From this course of the vascular bundle is deduced the following statement: *The doctrine laid down by* DESFONTAINES, *that the new vascular bundles originate in the centre of the stem, and that the harder and thicker vascular bundles, situated at the periphery of the stem, are older than the soft ones occupying the centre, and that, therefore, the vegetation of Monocotyledons is wholly different from that of Dicotyledons, is altogether incorrect and inadmissible.*

Obs. 1. From the circumstance that the vascular bundles run from the leaves to the middle of the stem in a curve of small radius, but that from here, in their way downward, they only approach the rind gradually, we can understand how phytotomists have been led to assume that they originate in the middle of the stem. Indeed, this outward course is not easily observed in a stem split longitudinally, unless the single vascular bundle is dissected out. One circumstance, however, must have long since indicated the incorrectness of Desfontaines' doctrine. If, namely, the vascular bundles of the younger leaves lay more internally in the stem than those which go to the older leaves, the former could never cross the latter. Now, it is easily seen in all Palms, that the vascular bundles entering a leaf, cross those which run to the leaves situated higher up, which is only possible by the arrangement of the fibres described above. This crossing is the more striking the thicker the stem and the closer its leaves, therefore much more evident in the species of *Cocos* than in *Kunthia*; it is still more distinct in *Xanthorrhœa hastilis* (vide De Candolle, Organogr. tab. 7, 8), in a transverse section of

the stem of which the vascular bundles entering the leaves have the aspect of medullary rays. The crossing is also very evident in the stem of *Pandanus*, *Dracæna Draco*, *Aletris fragrans*, *Aloë*, *Bambusa*, &c.

Obs. 2. The smaller diameter of the lower liber-like end of the vascular bundles simply explains the less degree of thickness of the fibrous layer of the stem. Where each vascular bundle ends in a single filament, as in *Bactris*, *Geonoma*, *Lepidocaryum*, *Calamus*, *Kunthia*, *Œnocarpus*, *Hyospathe*, *Rhapis*, &c., this layer is very thin; when, on the other hand, the vascular bundle gives off several fibres, or when, as in *Mauritia vinifera*, the fibres retain a considerable thickness, the thickness of the fibrous layer is not altogether inconsiderable. I found it in *Leopoldinia pulchra* from ½ to 2 lines; in *Syagrus cocoides* 1 line; in *Cocos nucifera*, *Euterpe edulis*, *Mauritia vinifera*, 6 lines thick.

The Cellular Tissue of the Palm-stem.

The cellular tissue is not, as in Dicotyledons, distributed into distinct bark, pith, and medullary rays, since the vascular bundles are scattered throughout the whole substance of the stem. Nevertheless, the cellular tissue exhibits different forms in the different layers of the stem, which may in many respects be compared with the forms of the cells of the bark, pith, and medullary rays.

The form of the cellular tissue in Palm-stems in general possesses but one definite character, namely, it is parenchymatous, and its cells are usually arranged in perpendicular rows, the forms of these cells varying much, not only in different species, but in different layers of the same stem. In general, these cells are only of a medium size, and apparently in all species, at a certain period of vegetation, densely filled with starch.

In the fibrous layer, the cellular tissue is composed of small, thin-walled cells, mostly expanded transversely, between which are small intercellular passages. In young stems, the cortical layer of which is still in full vegetation, chlorophyll-granules are found in the outer cells, starch-granules in those lying deeper; the granular formations subsequently disappear. The cells of this layer only

form a perfectly regular tissue where the fibrous bundles lie far apart; in most cases the regularity of their arrangement is destroyed by the cells lying next the vascular bundles having their broad side, or more rarely their narrow side, directed towards the vascular bundle, in which latter case a stellate figure is formed round each bundle (*Leopoldinia pulchra*).

In that layer of the stem in which lie the thick, hard vascular bundles, the cellular tissue becomes compressed into thin lamellæ, from the vascular bundles lying very densely crowded here, and by their mutual pressure frequently (especially in cylindrical stems) forcing them to assume an angular figure; these lamellæ indeed have a very variable direction according to the form of the vascular bundle, but taken as a whole, run from without inward, since the vascular bundles mostly exhibit a form compressed on both sides. The cells are also here transversely expanded in the direction of the lateral faces of the vascular bundles, and so much the more, the nearer they lie to the vascular bundles; therefore they have in the cylindrical stems, in which at most only 1 to 3 rows of cells lie between every two vascular bundles, a very much elongated form, while in other stems this only occurs from accidental approximation of vascular bundles, and the dodecahedral form of the cells reappears in all places where the vascular bundles lie further apart. In proportion as the cells assume a transversely extended form, the superposition in perpendicular rows becomes converted into an arrangement in horizontal rows, so that the cellular tissue assumes the so-called muriform character. In many Palms, e. g. *Cocos botryophora*, the outer vascular bundles stand behind one another in radiating rows, so that broad strips of cellular tissue penetrate from 1 to 3 lines deep into the stem in the form of medullary rays. In these strips, the cells exhibit lateral expansion parallel to the surface of the stem.

The cells of this layer almost always have much thicker and harder walls than those of the fibrous layer and the

interior. The thickening of their walls is usually indeed, although always noticeable, not very striking, but in certain Palms, on the contrary, e. g. *Diplothemium caudescens*, *Cocos botryophora*, they attain such thickness as we are only accustomed to see in wood- and liber-cells. In consequence of this thickening of the walls, the dots (which in general occur in all Palm-stems) are converted into distinct canals, which correspond in contiguous cells. In these two conditions, the thickening of the walls and the punctation, these cells approach no less than in their form, the cells of the medullary rays of Dicotyledonous trees, since these also are constantly thick-walled and punctated.

The cellular tissue of the central part of the stem exhibits in like manner many variations, which in great part are connected with the position of the vascular bundles. In all Palms it agrees in these characters—the cells are thin-walled, in most cases arranged in perpendicular rows; the cells lying upon the vascular bundles are mostly somewhat elongated, and depend for the direction of their transverse diameters on the position of the vascular bundles.

In the interior of the *Cocos*-like stems, the cellular tissue exhibits a regular parenchyma, the cells are thin-walled, finely punctated, and only in the investment of the vascular bundles, or where two bundles lie near together, do they form transitions to the muriform cellular tissue, without, however, thereby acquiring thicker walls; in *Cocos botryophora* and *Diplothemium caudescens*, the cellular tissue even becomes thinner-walled the nearer it lies to the centre.

In most Palm-stems, on the other hand, in which the vascular bundles stand much further apart in the middle than at the circumference, the cellular tissue of the centre exhibits considerable differences from that of the outer layers, becoming very lax, and this in two ways.

In some cases the cellular tissue in the middle of the stem has very large cells, and thus forms a very soft,

spongy mass; e. g. in *Geonema simplicifrons*, *Œnocarpus minor*, *Kunthia montana*. In these instances only the smaller cells, forming the boundaries of the vascular bundles, retain the form of regular parenchymatous cells; the rest, very much enlarged, run out in a radiating direction from the vascular bundles, and form as many stellate rosettes as there are vascular bundles. In other cases, the cells in the central portion of the stem do not attain to such considerable dimensions; but the tissue is rendered lax by the intercellular passages becoming enlarged into regular air-canals. *Calamus* forms the transition here, in which large intercellular passages occur between the cells in the middle of the stem; these, however, still preserve too much of the form of regular parenchymatous cells, and the intercellular passages are still too small, to allow of our properly reckoning this cellular tissue under the so-called compound form. This occurs to a great extent, however, in *Astrocaryum gynacanthum*, *vulgare*; *Mauritia vinifera*, and especially in *Mauritia armata*. Here the cells leave between them large roundish canals, which run in unbroken continuity through long tracts in the stem, so that one can blow smoke through pieces of the stem more than a foot long. At the extremities these canals are gradually attenuated till they become completely closed, for the septa of stellate cells, such as are found in many aquatic plants, in *Musa*, &c., do not occur in the Palms.

Obs. 1. Certain German phytotomists (Heyne, Meyen) have recently sought to distribute the cellular tissue into a great number of subdivisions, according to the form of the cells; this appears to me contrary to nature, on account of the abundance of intermediate conditions between all these forms. The above description of the cellular tissue of the Palm-stem may serve as a testimony that the form of the cell stands in no close connexion with its function, and that it depends quite as much upon the form, organization, and position of the adjacent cells and vascular bundles, as on the special nature of the cells. In comparing the stems of different Palms it is unmistakeable that cells, lying in corresponding places in different species, which have a similar import in the economy of the plants, exhibit wholly different, often variable forms, and it therefore appears quite improper to attach so much importance to the form of the cells.

The Palms are the more fitted to afford this evidence, since the plants not only form one of the most natural families, but also manifest a very great similarity, both in respect to their vegetation and their products. The same conditions, deviation of form of the cells in nearly-allied plants, may also be demonstrated in other no less natural families, for instance, in the Ferns.

2. I did not find raphides or other crystals in the cells of any Palm-stem.

The Palms have not a *bark* distinctly separate from the subjacent parenchyma, and exhibiting a special growth, such as occurs in Dicotelydonous trees; but the outer layers of the cellular tissue are remarkable, and therefore deserve description. In the young condition they have thin walls, and cannot be distinguished from the cells of the subjacent fibrous layer; in more advanced age, however, their walls are thicker, and become hard and brown. In many species—for example, in *Calamus*, in many species of *Geonema*—this layer remains very thin; its cells do not acquire such thick walls, and appear to retain their vitality throughout the whole life of the plant. In other species, on the contrary, the surface of which is subject to destruction by atmospheric influence, as in *Cocos*, *Elais*, the rind acquires a considerable thickness, and gradually draws a portion of the fibrous layer into its circle. In such case this is not of equal thickness at all points of the circumference of the stem, but passes deeply into the fibrous layer in particular places, while in other situations it is rather thin. Under these circumstances, the inner layers of the rind inclose a portion of the fibrous bundles, which is not usually the case.

The *epidermis* exists in old age only in the cane-like and calamoid stems; in the rest, it is more or less destroyed by the action of the weather. It consists of a simple layer of minute cells. As a general rule, no stomates occur in it, but they do exist scattered in *Rhapis flabelliformis*. In *Calamus*, it consists of minute cells elongated in the direction from without inward, and forms a stony, brittle, shining layer.

The different kinds of pubescence also come under consideration as appendages of the rind and true cellular

parts. The youngest portion of the stem is frequently clothed with a hair-like covering, so long as it is still young and inclosed by the leaf-sheaths. Sometimes this appears in the form of actual hairs, which are mostly closely crowded and coherent into a dense felt; e. g. in *Bactris tomentosa*. In other cases, the covering is composed of scales (*ramenta*), which exactly resemble those of the Ferns; e. g. in *Rhapis flabelliformis*, *Phœnix dactylifera*. In other instances the cells are combined into spines of various dimensions. On the leaf-sheaths and spathes many transitional forms are met with, from simple hairs, stiff bristles, to strong, hard spines. Spines of this kind exist on the stems of many Palms, lying closely appressed to it, so long as the internodes are included in the leaf-sheaths; but erecting themselves after the fall of the leaf, they form a terrible defence to the stem by their hardness, length, and prickly points.

The spines are sometimes blunt cones, but about an inch long, as in *Mauritia armata;* in *Acrocomia sclerocarpa*, *Astrocaryum Murumurù*, *Ayri*, *gynacanthum*, &c., on the contrary, they form long, slender, very hard and acute needles. These are only cellular structures; the cells of the outer layers are elongated, hard, and have very thick walls, those in the middle are thin-walled and parenchymatous; the middle of the spine is often hollow.

Structure of the Vascular Bundle.

Before I describe the modifications which the structure of the vascular bundle undergoes in the different parts of its course, it may not be out of place to state its composition in those situations at which, from the hard peripherical cylinder of wood, it enters, on its way to the centre, the soft middle substance of the stem. It here consists of three constituents, which may be clearly distinguished from each other: 1, of liber; 2, of a bundle of proper vessels (*vasa propria*); and 3, of the ligneous

body. These three constituents are constantly applied together in such a way that the liber is directed toward the periphery, the wood toward the centre of the stem, and the proper vessels lie between the liber and wood. As a general rule, the following is the minute structure of the different portions.

The *liber* (Bast) consists of thick-walled, prosenchymatous cells. The opinion of Kieser, therefore (Phytotomie, 209), that the liber-cells of the Monocotyledons have horizontal septa, was altogether unfounded; and indeed Moldenhawer (Beiträge, 48) had already found a prosenchymatous liber in the Grasses. The liber-cells manifest no definite arrangement in their corresponding positions; those lying toward the interior of the vascular bundle are of the smallest diameter. They have fine dot-canals (Tüpfelcanalen, canals of the pores).

The *proper vessels* are composed of a combination of much elongated cells, with horizontal septa, thin walls, and of various diameter. The narrower lie partly between the angles of the wider, partly between the lateral walls of the others.

The *wood* consists of elongated parenchymatous cells, with thin walls, and porous, among which, on the side directed toward the periphery of the stem, usually lie two large reticulated vessels, and behind these a variable number of narrower spiral and annular vessels.

The structure described is not retained unaltered by the vascular bundle throughout its whole length, but its structure changes in the different parts of its course in an analogous manner in all Palms. To demonstrate this, two methods may be adopted, to investigate either the transverse section of an entire stem, or an isolated vascular bundle in the different parts of its course.

In the investigation of the transverse section of a Palm-stem, we can indeed become acquainted with the structure of any one of its vascular bundles only at one point of its course; since, however, each of these vascular bundles has a definite course from the periphery to the

centre, and from this again outwards to the periphery, it is clear that in every transverse section of the stem we must meet with the fibrous inferior extremities of the vascular bundles at the periphery; further in, the thick and hard part of the bundles formed further up; and toward the middle of the stem, the soft part of the bundles in the situation of their more vertical course beneath their point of curvature; finally, we may meet with the portion of the bundles, in which they run from the centre toward the leaves, in the most varied situations, among the others. The last vascular bundles will be cut through more or less obliquely, the rest in pretty nearly a fair transverse section.

The examination of such a transverse section by the microscope, shows that the outer fibrous bundles are composed solely of thick-walled prosenchymatous cells, which correspond to the liber-cells of the other vascular bundles. More toward the interior, we meet with large bundles, which already exhibit the perfect composition of the vascular bundle; they are distinguished by their liber-mass being relatively very large, and by having the wood consisting of a single vessel surrounded by but few cells. The proper vessels likewise exist only in small numbers. Further inward, where the vascular bundles have attained their most considerable size, they are composed in greatest part of thick-walled, lighter or darker brown cells, the wood is still but slightly developed, yet contains already one or two vessels of tolerable size, which are inclosed by few, somewhat thick-walled, cells; the proper vessels are also but little developed, and are readily distinguished from the wood-cells by their thinner walls. Still further inward, in the transition to the soft part of the stem, the size of the vascular bundles diminishes; they exhibit a rounder form, since the liber-mass is considerably smaller and assumes the form of a crescent, in the concavity of which the proper vessels are received, and behind these lies the strongly developed woody portion. In this occur one or two large vessels, with several smaller behind them. The

nearer to the centre the vascular bundle lies, the more the liber is diminished in mass, till at last it displays only a very thin crescent, while the size of the woody mass increases in the inverse ratio, the smaller vessels lying at its inner side increasing in number. The bundle of proper vessels enlarges in similar proportion to those of the woody mass. The softness of the whole vascular bundle increases with the diminution of the mass of the liber, because the liber alone contains the thick-walled elementary organs.

Similar changes in the structure of the vascular bundle are met with, when it is dissected out from the stem and examined in different parts. In this way we may not only obtain, by comparison of transverse sections of one and the same vascular bundle, a survey of the changes of its size and structure which leaves no room for doubt, but we may detect more readily than in the cross section of an entire stem, the changes which the vascular bundle undergoes in its way from the centre of the stem to the base of the leaf.*

These changes are as follows: the nearer the vascular bundle approaches to the leaf, the more the liber-mass diminishes in size and the woody portion increases, a great multiplication of the vessels of the latter being connected with this, these, however, considerably decrease in size. In the vicinity of the point of emergence from the stem, a division of the vascular bundle into several (up to six) portions already begins to be effected, this taking place in such a manner, that small bundles of liber appear on the outer borders of the woody portion, at its posterior and lateral surfaces, behind which, and at some distance higher up, are found the rest of the systems (wood and proper vessels) belonging to a perfect vascular bundle, so that the entire vascular bundle consists of a circle of smaller bundles, which all have their woody por-

* What relates to these two methods of investigation is not a translation of the original text, for the latter referred specially to the illustrations here, and therefore would be incomprehensible without them. (H. v. Mohl.)

tions directed toward a common centre, and by the simple separation of these subdivisions, it becomes decomposed into just so many bundles containing all the essential parts of the vascular bundle.

From the character of the vascular bundle, as above described, follows incontrovertibly the total falsity of the generally received opinion, that the thicker and firmer vascular bundles lying in the outer parts of the stem are the older and lignified, and that the softer, lying in the middle, are the younger, not yet come to their complete development.

*Modifications of the Structure of the Vascular Bundle in various Palm-stems.**

Although the structure of the vascular bundle exhibits a common type in all Palms, modifications occur in the different species.

In the cane-like stems, the liber of the outer hard layer of the stem displays a very considerable development; toward the centre it, indeed, diminishes again in volume, yet still retains a moderate size, and since the the vascular bundles are not very distinct from each other, the middle of the stem possesses tolerable solidity.

In the cylindrical stems, the liber of the outer layers exhibits the greatest development that occurs in the Palms, into a mass often elongated in the direction from within outwards; in the middle of the stem the vascular bundle acquires an herbaceous softness, partly through the diminution of the liber-bundle, partly through the walls of its cells becoming so very thin, that in a cross section they resemble parenchyma-cells.

In the cocos-like stems the liber only increases slowly in the passage of the vascular bundle from the fibrous layer toward the interior, and does not attain any considerable size; the vascular bundles of the outer parts of

* This portion consists of extracts, since the detail in the original referred to the illustrations. (H. v. Mohl.)

the stem are also in a less crowded condition than in the two preceding forms. Partly by this, and partly by the smaller amount of decrease of the liber in the middle of the stem, is explained the more uniform hardness of the different layers of the latter.

The vascular bundles of *Calamus* exhibit a very peculiar structure. The liber is here also strongly developed in the outer layer of the stem, but the woody portion displays this peculiarity, that, disregarding rare exceptions, instead of several large vessels, it contains only one of unusual dimensions, occupying the centre of the bundle. Behind this large vessel (except in the outermost vascular bundles) lie small spiral vessels. The cells of the woody portion have thick walls, and thus may readily be confounded with the liber-cells in a cross section. The proper vessels are distributed in two groups, which, with the spiral vessels, form as it were the points of a triangle inclosing the large vessel.

Of the Structure of the particular Anatomical Systems of the Vascular Bundle.

The cells of that part which I denominate *liber* always have a diagonal septum. In a young condition, they, like all other thick-walled cells, are composed of delicate, colourless membrane. When with increased age they have become thicker, they afford clear evidence that the membrane of the vegetable cell grows in thickness by the deposition of layers. In transverse sections of the walls of the liber-cells of all Palms, delicate concentric lines may be seen, and that these lines form the boundaries of the different layers composing the cell-membrane, is manifest from the fact that sometimes, when the section has been made with a razor which is not very sharp, these layers separate from each other, and the slice of cell-membrane appears in the form of distinct concentric rings. Frequently the colour of these cells is not uniform throughout the whole thickness of the membrane, and

some of the component layers are often of a darker hue than the rest.

A second remarkable peculiarity of these cells is their porosity. Both in the transverse and longitudinal sections we see fine striæ, which run from the cavity toward the outer surface of the cell. When a high magnifying power is used, there remains no doubt that these striæ are canals perforating the cell-wall. As a general rule, their diameter does not exceed $\frac{1}{2000}$ of a line. As in the case of the pores of cellular tissue, the canals of adjacent cells correspond to each other.

The second constituent of the vascular bundle, which I have termed *wood*, is composed of two organic systems, cellular tissue and vessels.

The cellular tissue of this woody portion consists of colourless parenchymatous cells, the walls of which are not very thick. They are usually somewhat elongated, stand in vertical series one above another, with horizontal septa; never lie in series diverging like a fan from the hindmost point of the woody mass, but form an irregular parenchyma, the cells of which, in the vicinity of the vessels, are arranged according to the form and position of these latter. These cells never contain starch-granules; their walls are studded with large and small pores like the cells of *Cycas*.

The woody mass, as already mentioned, always lies at the inner side of the vascular bundle; but in the transition of the fibrous bundle, devoid of vessels, into the condition of vascular bundle, it is very frequent, and almost the rule, for the woody mass to lie, not at the inner side, but in the middle of the liber-bundle. In the vascular bundles of the outer, hard layers of the stem, also, a narrow strip of liber-tubes often runs round the posterior face of the woody mass, so that this is completely surrounded by liber-tubes.

In other cases the membrane of the wood-cells is itself thickened, and thus they acquire a resemblance, at least in the cross section, to the liber-cells; however, they are

mostly to be distinguished from these by their larger cavity and somewhat thinner walls, and in the longitudinal section by the septum being, at all events in the vicinity of the vascular bundle, horizontal. This thickening occurs sometimes here and there in the outer bundles of many Palm-stems, e. g. in *Kunthia montana*, in which case it is met with in one vascular bundle and not in the others; or it is a structure occurring regularly in all bundles, which, however, is only the case in *Calamus*. Notwithstanding that there is here a great similarity produced to the liber-cells by the thickening of the walls, they may be distinguished from these by the somewhat thinner walls, a larger cavity, as well as by the circumstance that, with the exception of the hindermost, they are elongated in a direction parallel to the wall of the large vessel. Their walls, like those of the liber-tubes, consist of several layers, and possess pore-canals, which are particularly striking in longitudinal sections, since from their small distance from each other, the cell-wall cut through possesses almost a moniliform aspect; and under these circumstances the nature of these canals, as excavations perforating the cell-wall down to the outermost layer, may be recognised most clearly.

The *vessels* of the Palms must be divided into the large and small. Each of these kinds, as is clear from what has been said already, occupies a definite place in the vascular bundle. The large vessels, traced from the lower fibrous extremity of the vascular bundle to its exit into the leaf, do not anywhere exhibit the form of the spiral, but that of the scalariform or reticulated vessel. These vessels are composed of rather short tubes, standing one above another. This composition may be perceived even by the naked eye in the very wide vessels of *Calamus Draco*, *Mauritia vinifera*, &c., the length of one of the tubes in these plants amounting to 1—2 lines. The face where the ends of the tubes meet one another is very seldom horizontal, but mostly inclined considerably toward the axis of the vessel. As a general rule, the ends

of the tubes do not lie one behind another in the direction of a line drawn from the periphery to the centre of the stem, but side by side. The tubes do not always succeed one another singly in the longitudinal arrangement, for frequently two or three stand next below a single one, so that in the cross section there appear to be 2—3 vessels side by side. This occurs sometimes even low down in the vascular bundle, in which case these vessels often again blend into a single one. Some of these vessels attain a very considerable size. In the lower part of the course of the vascular bundle, they have indeed scarcely a diameter of $\frac{1}{200}$ of a line; but the vessels occurring in the middle tract are among the largest that are met with in the vegetable kingdom: thus the vessels of *Bactris mitis* exhibit a diameter of from $\frac{1}{50}$ to $\frac{1}{25}$ of a line, those of *Desmoneus mitis*, *Œnocarpus minor*, $\frac{1}{23}$ to $\frac{1}{17}$, of *Astrocaryum gynacanthum* $\frac{1}{17}$ to $\frac{1}{13}$, *Corypha cerifera* and *Mauritia armata* $\frac{1}{13}$ to $\frac{1}{10}$, *Mauritia vinifera* $\frac{1}{8}$ to $\frac{1}{6}$, *Calamus Draco* $\frac{1}{7}$ to $\frac{1}{5}$ of a line.

The walls of these vessels universally exhibit the form of a dotted tube.* But the nature of this varies according to the nature of the adjacent parts. As this circumstance has almost entirely escaped phytotomists, a more minute exposition of it may not be out of place here. I have already pointed out, that in cellular tissue the position of the pores of one cell exerts a definite influence over the position of the pores of the adjacent cells, and that the pores of two contiguous cells always correspond. Now this occurs also in the reticulated vessels. It is a universal law in the reticulated vessels and scalariform ducts of all plants, that the dots and slits of their walls are somewhat shorter than the breadth of the cell or vessel in contact

* In the Latin original I have called them *vasa porosa, v. punctata*, because the term reticulated vessel did not appear to me adapted to the kind of punctation. But since I have subsequently found that the pores of dotted vessels of the Dicotyledons are distinguished from those of the vessels of Palms, by the fact that there is a cavity between each pair of pores in the former, which is wanting here, I now select the expression reticulated vessel, to avoid the necessity of making a new term.

with them. Since, as a rule, the vessels are surrounded by elongated cells, and the lateral walls of these cells, perpendicular to the vessel, run down some distance vertically upon it, this causes the well-known appearance that the dots or slits lie in a straight row, one above another, in the vessel. In the Palms, the vessels are, in most cases, surrounded by short, dodecahedral parenchyma; since, therefore, in accordance with the above law, the pores are only formed at those places in the vessel at which the parallel walls of the neighbouring cells are grown to the wall of the vessels, these vessels exhibit an apparently irregularly grouped distribution of the pores and, between these groups of pores, free interspaces, which correspond to the perpendicularly-placed side and cross walls of the adjacent cells.

In other cases, where elongated cells are in contact with the vessel, the pores lie in regular vertical rows. When two vessels are directly applied together, the pores of the lateral walls, grown to the other vessel, assume the form of transverse slits, which are as long as the breadth of this wall, whereby the vessel becomes scalariform, while the other sides, in contact with cells, possess the form of the reticulated tube. These relative conditions are not peculiar to the Palms, but occur in the same manner in other plants, for instance, most distinctly in the Tree-ferns.

Obs. It is further to be noticed, that cases also occur in which the pores have not the whole breadth of the adjacent elementary organ. For instance, it not unfrequently happens that the pores are a good deal shorter, and lie in regular horizontal lines, intermingled with longer slits. I found a peculiar deviation from the general rule, that the pores of two adjacent vessels correspond exactly in position, form, and size, in *Corypha cerifera*, where one vessel was studded with longer slits, while the other possessed rows of roundish or elliptical pores corresponding to these slits.

Both the investigation of full-grown vessels and their development, presently to be discussed, prove that the pores and slits are not actual openings, but are closed by a delicate membrane at the outside. This may be

perceived most clearly when a longitudinal section passes through the adjacent walls of two scalariform ducts, in which case we recognise distinctly that the slits are actual excavations in the walls of the vessels, and not elevations, as stated by Bernhardi (Ueber Pflanzengefässe, p. 35), Treviranus (Beiträge, p. 22), and Meyen (Phytotomie, p. 253), but that the interspaces between the slits form elevations which project into the vessel. It may likewise readily be perceived that a membrane is stretched between the fibres, separating the fibres of the two vessels under the from of a simple, dark line. The development of these vessels shows that this membrane forms a tube inclosing the fibres. The pores and slits equally exhibit an evident rim, which does not depend, as Mirbel assumes, on the presence of a projecting border, but is, on the contrary, caused by the borders of the slit being truncated by an oblique surface.

In many cases, as in *Calamus* for example, the place where two vascular tubes are connected is conspicuous, from each tube ending in a broad ring; the two adjacent rings form a band surrounding the vessel, as Moldenhawer has shown long since in other plants. When the tubes meet by such a ring, they are freely open to each other. In other cases, on the contrary, particularly in *Desmoneus mitis, Cocos nucifera, Mauritia vinifera, armata, Kunthia montana, Astrocaryum gynacanthum, vulgare, Corypha frigida,* no such rings are seen at the points of connexion of the tubes, and in these are found septa. The existence of such septa is indeed denied utterly by all phytotomists; but having observed them hundreds of times, not only in the Palms, but in many other Monocotyledons, and even in many cases in the porous vessels of Dicotyledons, I do not hesitate to assert their existence in the most positive manner. The direction of these septa is usually such that we obtain a front view of them in a longitudinal section made in the direction of the radius of the stem. They differ completely from all other membranes of plants, in being formed of a reticulation of thick fibres, with large openings between them. In the stems of Palms

where these septa cut the axis of the vessel obliquely, and therefore are elliptical in form, the fibres are mostly horizontal. At the two rounded extremities of the septum the orifices present the form of little slits or round holes, in the middle of broad slits or oval openings, and at both sides of the septum likewise occur smaller, roundish, or ovate orifices. Each of these orifices is bounded by a narrow rim. In other cases, the orifices exhibit the form of narrow, transverse slits, giving the septum quite a scalariform aspect. The openings are usually actual perforations, very rarely a thin membrane is stretched over them. The fibres of the septa are double, and the rim originates from the same cause as in the scalariform ducts. These septa occur very frequently in the Palms; in many species, however, as for instance in *Cocos nucifera*, they do not occur at every point of junction of two vessels, for some of these end in the ring above described. To avoid the necessity of recurring to these septa in the examination of the root of the Palms, I will mention here, at once, that in the large vessels of the roots the septa are usually perpendicular to the axis of the vessel, and therefore of roundish shape. In this case they are not scalariform, but reticulated, perforated by large, roundish, and many small punctiform orifices. The course of the fibres does not always correspond exactly in the two component plates of the septum, whence a portion of one plate often projects into the opening of the other.

In the porous vessels of the Dicotyledons it is well known that vesicular cells often occur, which Kieser believed to be composed of the same membrane which forms the wall of the porous vessel, whence he assumed (Phytotomie, p. 237,) that such vesicles could by no means occur in the Monocotyledons. I however found, though indeed but seldom, vesicular cells, similar to those of the Dicotyledons, in the large vessels of the Palms, for instance, in *Corypha cerifera*.*

* I have not traced the development of these cells in the Palms. Doubtless they have the same character as in the Dicotyledons, in regard to which from recent researches, I think that I am not wrong in assuming that they

The course of development of these vessels, which I investigated in the germinating date-palm, in the apex of the stem of *Rhapis flabelliformis*, and in the root of many species of Palms, and with which the development of the large vessels of *Dioscorea, Tamus elephantipes*, &c., fully agrees, is as follows: In young shoots, we find in the situation where the large vessels subsequently lie, perfectly closed, large, and cylindrical tubes, which are composed of a colourless and very delicate membrane. In tubes a little older, we find a network of very delicate, transparent fibres upon the internal surface; these have a horizontal direction, are connected at places which correspond to the longitudinal septa of the adjacent cells by perpendicular and oblique fibres. As a general rule, the horizontal fibres are so arranged that they are not continuous over several lateral walls of the vessel, but terminate where they reach a longitudinal septum of an adjacent cell, and here pass into a fibre, going obliquely upward or downward, so that a mesh of a fibrous network comes as a direct successor of the fibre on the adjoining side-wall of the vessel. From this it is most clear that these vessels are not originally spiral vessels, the fibres of which become reticularly connected by the subsequent development of cross-fibres. This is made still more evident by the fact, that in the first origin of the fibrous network, we in many cases meet with the fibres only perfected at particular places, the walls of the vessel appearing still perfectly smooth in other situations. The older the vessel grows, the broader and thicker its fibres become, and the interspaces between them are diminished in width in proportion, till at last they display themselves as mere narrow slits. The septa are perfected in a manner wholly analogous, but the original delicate membrane is generally destroyed, after a time, in the interspaces of the fibrous network.

are produced by a protruding expansion (a kind of *hernia*) of the adjacent cell, which penetrates the pore, and either tears through or causes the absorption of the primary membrane of the vessel.

That these vessels, though not the result of a metamorphosis of spiral vessels, belong to one and the same system, is evident from the fact, that spiral vessels occur in many Monocotyledons in the situation where the reticular vessels lie in the Palms, and in the Grasses, as Moldenhawer showed, the same row of tubes is developed at certain places into spiral, and at others into porous vessels.

The smaller vessels lying behind the reticulated are never reticulated, but always spiral or annular vessels, be the stem under examination as old as it may. The number of annular vessels in each vascular bundle is but small, in general only spiral vessels exist. When annular vessels do occur, they are always situated the farthest back in the bundle, the vessels lying nearer to the large vessels being always spiral. The turns of the spiral are always far apart, especially in those vessels which are farthest from the large vessels. It is easy to satisfy one's self of the presence of an outer membrane inclosing the spiral fibre.

I have mentioned above, under the name of *proper vessels* (*vasa propria*), a bundle of thin-walled cells lying between the wood and liber, as the third constituent of the vascular bundle. This bundle is distinguishable from the surrounding cells, both by the thinner walls of its elementary organs, and by narrow and wide cells lying intermingled in it. This part opposes considerable difficulty to anatomical investigation, on account of its soft texture, and also its great transparency. This circumstance explains why these proper vessels, although they occur in most of the Monocotyledons and in a portion of the Dicotyledons, have been overlooked by almost all phytotomists, for Moldenhawer is almost the only one who was accurately acquainted with them, in *Zea Mays* and *Bambusa*, while Amici saw them in *Calamus*, but did not recognise their nature, and Kieser, who likewise saw them in *Calamus*, explained them as spiral vessels; Bernhardi and Meyen, the latter of whom found these proper vessels in *Scirpus lacustris* and some other Mono-

cotyledons, regarded them as prosenchymatous cells, and distinguished them neither from the liber nor the wood. In a longitudinal section we perceive that the cells are elongated in these bundles, and stand one above another mostly with horizontal septa; the septa are, however, sometimes oblique, and the tubes not unfrequently terminate in a point. We may distinguish narrow and wide cells, frequently with a tolerably strong difference of diameter. Moldenhawer (Beiträge, p. 126) regarded the wider tubes as cells of the usual kind, and the narrow as proper vessels, which he referred to the same system as the milk-vessels of *Chelidonium*, *Asclepias*, &c. So far as my own investigations showed, I cannot agree with Moldenhawer in this distinction of wide and narrow tubes, for I frequently believed that I saw both containing an opaque, thickish sap, in which swam a great abundance of fine granules; I am, therefore, compelled to refer both to the same system. I never found the contained sap milk-white, but only more or less opalescent. I never could observe any currents, but only an oscillation of the minute granules, which appeared to me merely molecular motion. The septa between the tubes are completely closed. In the stem, the wide and narrow tubes are intermingled without order in the entire bundle, but a different condition will be met with in the root. In *Calamus*, the bundle of these proper vessels is not only divided into two separate portions, but the narrower tubes are frequently separated from the wider, as the latter often lie isolated, at the limit between the wood- and liber-cells.

I have denominated these tubes proper vessels, because the nature of their contents brings them nearest to the system known as the vital (Lebensgefässe) or milk-vessels; I shall bring proofs further on that they are different from this system. In reference to their development, I can merely state that, in the Palms as in other Monocotyledons, they precede the formation of the woody portion in so far that, when a fibrous bundle devoid of vessels

is traced upward to the point where it displays itself as a perfect vascular bundle, they show themselves sooner than the woody mass itself. However, this earlier development relates only to space and not to time. I do not venture to give an opinion as to the function of this system, and for the present am content to have demonstrated their existence anatomically.

Comparison of the Palm-stem with the stems of other Monocotyledons.

With regard to the *course* of the vascular bundle, the Palms stand nearest to *Dracæna*, *Aletris*, and *Aloë*; with reference to the *organization* of the bundle, to the Grasses.

As to the structure of the vascular bundle of the Grasses, I refer to the excellent researches of Moldenhawer, and merely mention here, that in the Grasses the vascular bundle not only increases in size from the periphery toward the centre of the stem, but its structure is altered at the same time, in a manner analogous to what occurs in the Palms. Beneath the surface of the stem we meet with fibrous bundles without vessels, then fibrous bundles containing a bundle of proper vessels, and these are adjoined by vascular bundles with reticulated vessels, while small vessels occur, in addition, in the inner. The perfect vascular bundles, for example, of *Arundo Donax*, contain two large vessels surrounded by thin-walled wood-cells, behind these lie a row of two or three small vessels; the hindmost portion of the wood-cells is composed of a mass of thick-walled, dotted prosenchyma, as also frequently occurs in the leaves and other organs of the Palms. Between the wood and the liber lies a bundle of proper vessels, the large cells of which are mostly quadrangular, and have a narrower cell lying between their angles.

In *Dracæna* and *Aloë*, the former of which is especially interesting on account of the minute researches on its

growth in thickness by Dupetit-Thouars, we meet with a structure of the vascular bundle which is aberrant in many respects. In a cross section of the stem of these plants, two evidently distinct layers may be detected, the inner being soft and pith-like, and acquiring no increase of size with the age of the plant, while the outer forms a firm mass, and gradually increases in thickness with the age of the plant. Anatomical investigation demonstrates that the inner soft substance has wholly the structure of the Palm-stem, its vascular bundles running in the same way from the periphery to the centre, and from this to the leaf. The most external of these bundles are smaller, poor in vessels, and closely crowded, the inner consist of several rows of dotted liber-tubes, a bundle of proper vessels, and a woody portion, which differs from that of the Palms only in so far that its large vessels are not isolated, but united with the smaller vessels into the form of a crescent. Tracing these vascular bundles downwards, we see them enter the outer firm layer of the stem; instead, however, of running down the stem in the form of fine fibres into a laxer cellular tissue, as in the Palms, they retain a considerable diameter, notwithstanding that they lose their woody portion, since the prosenchymatous cells of which they are composed are very wide. They contain a small bundle of proper vessels in the centre. Under this form they run downward in the stem, as in the Palms, but are not isolated, for they unite together laterally into a network, like the ligneous bundles of the Dicotyledons. The parenchyma in which they are imbedded consists of tolerably thick-walled, porous cells, elongated in the radial direction. This outer firm layer therefore corresponds to the fibrous layer of the Palms. No trace of it occurs at the apex of the stem, since it is composed of the lower extremities of vascular bundles: the lower down in the stem we examine, the thicker this layer appears, and thus the stem is conical and not cylindrical. The younger layers of the evascular fibrous bundles are applied upon the outer side of the older, and

hence injured places upon the stem, over which no new layers are deposited, are gradually converted into depressions. On account of this continuous deposition of new layers, the assertion made by Dupetit-Thouars (*premier Essai*) and received into all botanical works, that the stem of *Dracæna* does not increase in thickness so long as it remains without branches, is incorrect, and it is easy to convince one's self of this by the comparison of young and old specimens; thus, I found that the stem of a *Dracæna Draco*, two feet high, was only about one inch thick, while trunks twenty to thirty feet high had attained a thickness of from four to six feet, although devoid of branches.

Aloë has exactly the same structure as *Dracæna*, only the outer firm layer is very thin in proportion to the soft centre. Thus, in a stem of *Aloë glauca* two inches thick, it was only two lines; while in a stem of *Dracæna Draco*, two inches thick, it had already reached a thickness of six lines. The vascular bundles of *Aloë* resemble those of the Palms still less, for the vessels are scattered irregularly in the woody portion; however, the anterior always have the form of reticulated, and the posterior of spiral vessels.

Comparing the stem of other Monocotyledons with that of the Palms, in reference to the course and organization of the vascular bundles, we find in all (excepting the very lowest forms), if not so great a similarity as in *Dracæna*, yet a great analogy. It is, namely, common to all Monocotyledons for the small evascular bundles to lie at the periphery of the stem, while those lying further in contain a bundle of proper vessels, to which succeed bundles possessing large and small vessels, while the fully developed lie toward the centre of the stem.

These bundles exhibit more or less deviation from those of the Palms, in reference to their intimate structure; but that they are all formed after one and the same type is unmistakeable. In general, the liber-layer is developed in a much less degree than in the Palms; for in many only the outer small bundles exhibit an investment of thick-walled, prosenchymatous cells, while

the inner possess but a few thin-walled, wide liber-cells, scarcely to be distinguished from the parenchyma-cells and proper vessels in the transverse section, e. g. in *Asparagus officinalis*, *Lilium bulbiferum*, *Orchis militaris*, and *Sagittaria sagittifolia*. When the inner bundles do possess thick-walled liber-cells, these exist but in small quantity, and form only a narrow crescent. Sometimes their diameter is so great in proportion to their thin walls, that these cells are only to be recognised as the organ so greatly developed in the Palms, by their position and their greater development in the outer bundles; for example, in *Musa paradisiaca*, *Hemerocallis flava*, *Tulipa gesneriana*, *Fritillaria imperialis*, *Ruscus Hypophyllum*, *Iris sibirica*, *Epidendron elongatum*, *Aloë Commelini*, and *Scirpus lacustris*.

The proper vessels occur throughout the whole series of Monocotyledons, and lie in the same position between the liber and wood as in the Palms; they also possess the same structure, and contain the same opaque sap. In many plants they are more developed in reference to number and size than in the Palms; e. g. in *Asparagus officinalis*, where single ones, lying toward the inner side of the bundle, exhibit uncommonly large cavities. In *Musa paradisiaca*, the proper vessels, with their thin investment of liber-cells, form a large bundle, lying separate, in part, from the woody bundle, and not much inferior to it in size. In *Dioscorea villosa* also, and *Tamus*, some of the vessels lying toward the interior are developed to an unusual size. In *Sagittaria sagittifolia* the proper vessels form about half of the entire vascular bundle, and are difficult to discriminate from the surrounding cells, since these likewise have very thin walls.

The woody portion consists, as in the Palms, of more or less elongated parenchymatous cells; its vessels may also be divided into large and small; but the large are not so much separated from the small in their position in most Monocotyledons, for all the vessels generally lie together. A resemblance to the vascular bundle of the Palms does, however, occur here in so far that the large vessels lie in front and at the two sides, and the smaller behind and between the former, so that the total mass of vessels forms a more or less regular crescent, with its concavity outward, as for instance in *Asparagus officinalis*, *Convallaria Polygonatum*, and *Lilium bulbiferum*. In all these cases the large vessels lying at the two extremities of the crescent are reticulated tubes, while the smaller, lying further back, have the form of scalariform ducts, and the smallest, most posterior, that of spiral or annular vessels. *Ruscus Hypophyllum* makes an exception to this arrangement, as the largest vessels here lie behind and toward the interior. One consequence of this crescentic position of the vessels is, that the bundle of proper vessels retreats back between the horns of the crescent, and thus is half inclosed by the wood; e. g. in *Asparagus*, *Convallaria Polygonatum*, and *Lilium bulbiferum*. This is the case in the highest degree in *Tamus* and *Dioscorea*, where the proper vessels are retracted so much between the

crescent formed by the vessels, that the large vessels come in contact again in front of the bundle of proper vessels.

The unusual form of these vascular bundles may be an apology for my entering somewhat more minutely into their structure. The vascular bundles of these plants lie in two circles alternating with each other, those of the inner being considerably larger. Each of these vascular bundles is composed of a combination of three vascular bundles: one, the largest of them, situated internally, consists of a crescent of vessels, the most anterior and largest of which are finely dotted reticulated vessels, while only the most posterior and smallest have the form of spiral vessels. The proper vessels belong to this bundle. In front of this occur two vessels of tolerable size, which in many cases are likewise connected by a number of smaller vessels into a crescent, the convexity of which is directed outwards. Behind these vessels lies a second bundle of proper vessels. It is therefore evident that each of these vascular bundles is formed by the blending of two vascular bundles. The structure of the vascular bundles of the outer circle, and of those formed in the slenderest shoots of *Tamus Elephantipes*, show clearly that the outer and smaller of these vascular bundles is also composed of two bundles; for in the vascular bundles of the outer circle, the crescent formed by the vessels of the larger bundle, looking inward, is more widely open, and the anterior vascular bundles separate into two, each of which possesses a bundle of proper vessels at its inner side. In the young shoots of *Tamus Elephantipes*, the structure approaches still nearer to that usual in the Monocotyledons, for the smaller bundle is either altogether wanting, or, if present, is likewise divided into two portions, which, however, do not converge toward the large vessels, as in the stem, but have their bundle of proper vessels lying at their inner side.

In the forms enumerated hitherto, the analogy of the vascular bundle with that of the Palms is so evident as to require no further demonstration in that respect. The forms in which the different vessels exhibit almost equal diameter—e. g. in *Hemerocallis flava*, *Tulipa gesneriana*, *Fritillaria imperialis*, *Orchis militaris*, *Iris sibirica*, and *Aloë Commelini*, are rather more removed; but here also the most anterior vessels are constantly reticulated, the posterior annular and spiral vessels.

It may not be superfluous to mention a structure which may readily give rise to errors. In the vascular bundles of many aquatic plants an air-passage occurs, possessing no proper walls; for example, in *Alisma Plantago*, *Sagittaria sagittifolia*, *Scirpus lacustris*, *Cyperus Papyrus*, &c. If merely a transverse section of these vessels be examined, this canal may easily be taken for a vessel, as happened with Bernhardi (über Pflanzengefässe, p. 16, in *Alisma*), and Meyen (Phytot. pl. vi, fig. 1, in *Scirpus*). The whole form of the vascular bundle becomes altered through this canal. In *Scirpus* and *Cyperus* this is not so much the case, the vascular bundle being in general

very similar to that of the Grasses; but in *Sagittaria*, in which exist many vessels of tolerably equal size, these accommodate their position to the air-canal, and form a crescent, convex to the outer side, enveloped by a large bundle of proper vessels. This is the case also in *Alisma Plantago;* only a portion of the vessels are also scattered irregularly in the woody portion. I did not find proper vessels in the vascular bundles of this plant, but the liber-tubes immediately adjoined the wood.

As I have already observed, the large vessels of the Monocotyledons, as a general rule, exhibit the form of reticulated vessels; but that this does not hold without any exception, is shown by the masterly researches of Moldenhawer, on the vascular structure of the Grasses. In these, however, the vessels are still reticulated in the greater portion of their course; in others, they exhibit the form of spiral vessels. Thus, in the petiole of *Musa paradisiaca*, a very large vessel occurs in the middle of the woody bundle, in place of which, in the middle vascular bundles of the stem, three or four vessels occur. Now this vessel, as a general rule, exhibits the form of a spiral vessel, with many parallel fibres; and only in rare cases—for instance in the lowest parts of the vagina of the leaf and in the rhizome—did I find the fibres of this vessel blended together, and this frequently merely at particular places. In the same way I found, as a rule, only spiral vessels in the stems of *Typha angustifolia*, *Sparganium ramosum*, and in the petiole of *Calla Æthiopica*.

I shall subjoin but a few words on the cellular tissue of the Monocotyledonous stem. It consists of large cells, mostly with thin walls, yet frequently having pores; they have intercellular passages between them, and exhibit a transition of form between the polyhedral and cylindrical. These cells become of smaller diameter towards the surface of the stem, with which is combined an increased thickness of the walls. This thickening occurs to such an extent in many Monocotyledons, at the place where the outer vascular bundles lie, that a firm ring is formed around the stem, for instance, in *Arundo Donax*, *Ruscus Hypophyllum*, *Asparagus officinalis*, *Convallaria Polygonatum*, *Lilium bulbiferum*, *Iris sibirica*, *Dioscorea villosa*, *Tamus Elephantipes*, *Sparganium ramosum*, *Triglochin palustre*, *Alisma Plantago*, &c. From their thickened walls, their smaller diameter, and elongated form, these cells resemble the liber-cells, but it would be a great mistake to compare this ring with the liber of the Dicotyledons, since:— 1. There are many plants, e. g. *Fritillaria imperialis* and *Tulipa gesneriana*, in which these cells are wide and less thickened in the walls, forming a distinct transition into the parenchymatous cells. 2. This ring is not sharply defined at its inner side, but passes gradually into the parenchyma of the stem. 3. The relation to the vascular bundles and the leaves is altogether different from that of the liber-bundles of the Dicotyledons to these. 4. Many herbaceous Dicotyledons exhibit this ring and liber-

bundles together with it. From these reasons it is inadmissible, although Link (Grundlehren, p. 143; Elem. Phil. Bot. p. 140) explains this ring as liber, a view which Kieser also propounded (Phytot. p. 72). This ring is very sharply defined at its outer side, and surrounded by parenchyma which represents the bark.

I have already expressed my opinion that the proper vessels lying in the vascular bundles are not to be reckoned as belonging to the milk-vessel system, in which the so-called vital sap is contained in *Chelidonium*, *Asclepias*, *Euphorbia*, *Musa*, *Ficus*, &c. This is clear from the fact that the vital-sap vessels do not occur in the place in which these proper vessels lie in the Monocotyledons, for the former lie isolated in the interspaces of the cellular tissue, chiefly in the vicinity of the vascular bundles, in the pith and the bark. But it is best proved by the existence of many Monocotyledons, in which both these kinds of vessel are met with, independently, each in its proper place, and in these cases the two kinds of vessel conveying wholly different sap. Thus it is known, for example, from Moldenhawer's researches (Beiträge, p. 134), that milk-vessels lie in the parenchyma in the vicinity of the vascular bundles in *Musa*, the sap of which, like that of *Sambucus*, assumes a red colour, and which was also recognised as vital sap by Schultz (Natur. d. leb. Pfl. i, 537). These vessels, then, are distinguished from the proper vessels in the vascular bundles by their different situation and by the red colour of their contents, which colour is never assumed by the sap of the proper vessels. The proper vessels in the vascular bundle of *Sagittaria* are no less clearly distinguished from the milk-vessels lying scattered in the parenchyma of the peduncle and petiole, for the latter convey a milky, the former a very transparent sap. In *Alisma Plantago*, likewise, the vessels filled with milky juice are wholly detached from the vascular bundles.

Comparison of the Vascular Bundle of the Palms with that of the Dicotyledons.

In order to place in a clearer light the connexion of the organization of Palms with that of the Dicotyledons, and in order to state more accurately the grounds on which I have called the different parts of the vascular bundle of the Palms, liber and wood, a comparison of the vascular bundle of the Palms with that of the Dicotyledons becomes necessary, since in the latter alone can there exist no doubt as to the true import of its parts.

In herbaceous Dicotyledons the vascular bundles stand

in a circle, and are separated from each other by strips of parenchymatous cells varying in breadth; the vascular bundle of *Laserpitium aquilegifolium* may serve as an example. We find in this a great quantity of irregularly distributed vessels, the larger of which lie toward the outside, the smaller toward the interior; the exterior vessels are porous and scalariform ducts, the deeper-lying ones spiral vessels. The cellular tissue in which the vessels are imbedded, consists of thin-walled, elongated cells, and narrow, thick-walled cells are only met with in the outermost parts of the ligneous body. The most posterior or internal part of the vascular bundle also contains thick-walled cells. In front of the vascular bundle lies a bundle of liber-cells, which is connected by a process on each side with the wood bundle; between the wood and the liber lies a bundle of proper vessels. It is here clear that this vascular bundle has entirely the same structure as the Monocotyledonous bundle, the only distinction that occurs being, that the woody mass is gradually increased in size by the deposition of new layers on its outside. The relations of the vascular bundle to the surrounding parenchyma are likewise identical with those which are found in the Monocotyledons furnished with an outer ring of thick-walled cells. The large thin-walled parenchymatous cells of the stem, which send broad processes corresponding to the medullary rays, between the vascular bundles to the bark or rind, acquire thicker walls between the anterior portions of the vascular bundle, and approach pretty closely in form to the liber-cells.

If we examine the young shoot of *Aristolochia Sipho*, we find here also a great similarity of the vascular bundles to those of the Dicotyledons,* the woody mass consisting of a thin-walled parenchyma, the cells of which do not lie in any definite order. In the back part of the vascular bundle are found minute spiral vessels; in front, large porous vessels. It is only in front of these large

* Qy. misprint for Monocotyledons.—TRANS.

vessels, after the woody mass has increased in size by further growth, that the wood-cells begin to arrange themselves in regular rows. In front of the wood lies a large bundle of proper vessels, which may be readily distinguished from the parenchyma by their thin walls, and the absence of chlorophyll-granules. This vascular bundle is distinguished from that of the Monocotyledons, by the fact that the liber does not stand in immediate connexion with the vascular bundles; but the liber-bundles grow together in waving lines, and are separated from the proper vessels by several layers of cells. We find the same structure in the vascular bundle of *Menispermum canadense.*

Comparing the vascular bundle of the Monocotyledons with that of the Dicotyledonous trees, we meet with a great resemblance, the posterior portions of the wood having the cells thin-walled, and placed in no regular order. The smallest vessels lie farthest back, and are spiral; nearer to the front lie larger scalariform ducts, and to these follow the large porous vessels. We do not come to the firmer portion of the wood until we arrive at the front of these, this wood being composed of thick-walled cells lying in regular rows, and of porous vessels.

From these facts it is most clear:

1. That the vascular bundle of the Monocotyledons exhibits the same composition, as that of the Dicotyledons possesses in its earliest condition.

2. That the part of the vascular bundle of the Palms, which I, in spite of its having no ligneous solidity, have denominated the wood, corresponds most closely with the innermost part of the ligneous body of the Dicotyledons, to which Hill applied the name of the *Corona.*

3. That in many Dicotyledons, also, a bundle of proper vessels lies between the liber and wood; besides the plants named, this may be found in *Spiræa Ulmaria, Aruncus, Fumaria officinalis, Echinops,* and *Mimosa pudica.*

4. That the portion composed of prosenchymatous cells,

lying in front of this bundle of proper vessels in the Monocotyledons, is not to be referred to the wood, but to be considered as the liber of these plants.

On the other hand must be mentioned, as distinctions in these structures:

1. That in the Dicotyledons, the formation of the vascular bundle is not concluded with the development of the *Corona*, as in the Monocotyledons.

2. That in very few Dicotyledons is there a bundle of proper vessels between the liber and wood.

3. That in most Dicotyledons the liber-bundle is separated from the wood-bundle by some layers of cells; that it does not exhibit such different degrees of development in different parts of the bundle; and that it never attains to such considerable firmness and size, as in many Monocotyledons.

It has already been observed that, besides the proper vessels, milk-vessels are met with in many Monocotyledons; the same occurs in many Dicotyledons; for instance, in the Umbelliferæ, where milk-vessels lie among the proper vessels in the wood-bundle, as well as in the pith and rind, while the milk-vessels of the Dicotyledons, e. g. in *Euphorbia*, *Asclepias*, *Morus*, *Acer*, *Sambucus*, &c., scarcely ever occur in the vascular bundles, but only in their vicinity, in the bark and pith. (See Bernhardi, über Pflanzengefässe, p. 53; Treviranus, Beiträge, p. 44; Moldenhawer, p. 126.)

Comparison of the Palm-stem with the Stem of Dicotyledons.

So long as Desfontaines' theory, that the young vascular bundles of the Palm-stem originate in the centre, is believed to be correct, no parallel can be drawn between the stem of Palms and of Dicotyledons, for in such a condition these stems would exhibit only distinctions, but no resemblances. Since, however, the course of the vascular bundle is quite different from what was formerly supposed, and since its structure agrees perfectly with that of the vascular bundle of the Dicotyledons, it appears to

me that a comparison between the stems of the two great classes of vegetables may be instituted without straining the facts.

Although the vascular bundle belonging to each individual leaf cannot be distinguished from the rest in the cross section of a Palm-stem—since the position in concentric circles (which should result from the similar course taken by all the vascular bundles going to one leaf) is variously distorted—yet we may imagine the vascular bundles going to each leaf united into a tubular layer. This tube, however, is not cylindrical, but forms an elongated cone. As long as the leaf which is supplied by these bundles remains the uppermost, the conical tube, composed of its vascular bundles, forms the most external layer of the stem. But when a new, higher leaf is developed, the vascular bundles going to this leaf form a new layer, which is developed on the outside of the last layer. Since, however, the apices of these conical layers are not closed, but the vascular bundles of which they are composed run outward again from the centre of the stem to reach the leaves, the above described crossing results, occurring between the vascular bundles which emerge into a leaf, and all subsequent bundles running up to younger leaves.

If we compare with this the structure of the first year's shoot of a Dicotyledonous tree, for excellent observations on which we are indebted to Dupetit-Thouars (Histoire d'un morceau de bois), we meet with a very similar course of the vascular bundles. The vascular bundles in it, running to the lowest leaves, which have formed the *corona* on the lowest part of the branch, and which we will designate A, pass in a curve outwards, and the vascular bundles supplying the next succeeding leaf above (B), lie with their lower portions on the outside of the bundles A, up to the point where these latter turn outward; above this they form the succeeding portion of the *corona* up to where they also pass outward into the leaf. We see, therefore, that the course of the vascular bundles

in the Palm-stem and in the one-year old shoot of the Dicotyledons is exactly similar, and that the conception of a different mode of growth, and the division of plants into Endogens and Exogens formed on it, is altogether opposed to nature.

I have always found the structure of the yearling shoot of the Dicotyledons, such as I have described; I cannot, therefore, agree with the description given by Schweigger (Beobacht. auf naturhist. Reisen, 107), which goes to show that in the Dicotyledons the upper leaves are supplied by the internal, the lower by the external vascular bundles.

In spite of this resemblance, we must not overlook the fact, that very important differences occur in the organization and growth of Dicotyledons and Monocotyledons. In the yearling stems of a Dicotyledon, the vascular bundles going to the higher leaves are interpolated in their lower part, between the liber and wood of the older. The wood of the younger thus becomes blended with that of the older, while in many cases the liber-bundles of these remain isolated. From this cause, the wood in the lower part of the stem becomes thicker, and the entire stem acquires a conical form. In the Palms, on the contrary, in the vascular bundles of which the liber and wood stand in the closest connexion, the lower parts of the younger bundles are never interposed between the wood and liber of the old, but lie isolated in the cellular tissue of the stem, nearer to the periphery than the older bundles. Thus neither the liber nor wood of the older bundles exhibit a deposition of new portions, but remain permanently in that stage of development, which they have attained at their original completion.

We must not consider it as an universal distinction, that in the Monocotyledons the vascular bundles do not unite laterally into a reticulation, since, on the one side, in *Dracæna*, *Aletris*, &c., the fibrous bundles of the outermost layers become connected together in this way, and on the other hand, in some of the herbaceous, and even in many woody Dicotyledons, for instance, in *Rosa* and *Rubus*, this lateral connexion of the vascular bundles does not exist.

The phenomenon that the Palm-stem grows but little

in thickness, which at the first glance seems to indicate a great difference of its growth from that of the Dicotyledons, is readily accounted for by the smaller size of the lower part of its vascular bundles. That it does not increase in thickness at all is not a perfectly correct statement, for it certainly does exhibit a slight enlargement by growth; this increase of diameter occurs in many Palms, for example, in *Areca oleracea* and *Iriartea ventricosa*, not so much at the inferior extremity as higher up in the stem, whence this acquires a spindle-like form. Since the lower part of the bundles is not thicker than a hair, it will be conceivable how many thousands of them may be formed beneath the rind of the stem, without increasing its diameter more than a single inch, which is so slight a growth that it is wholly overlooked.

I have already stated that the fibrous bundles in *Dracæna* become more strongly developed, and that the stem then grows in thickness as in the Dicotyledons. From the circumstance that these bundles, lying in the external layers of *Dracæna*, are nothing else but lower extremities of the vascular bundles of the stem, it is most evident that their growth and development is not to be regarded as anything different from the growth of the apex and the centre; and that the idea of a double growth, which Mirbel (Annal. du Muséum, xiii, 67) imagined that he found in *Dracæna*, *Yucca*, *Aloë*, *Ruscus*, *Smilax*, *Dioscorea*, and *Tamus*, is no less incorrect than the idea of the central vegetation generally attributed to the Monocotyledons.

Obs. 1. I have mentioned above that Moldenhawer had already expressed himself against the correctness of the view of Desfontaines. Moldenhawer distinguished in the same way, as has been done above, in every vascular bundle of *Zea Mays* and *Bambusa*, in which plants his investigations were chiefly made, liber, proper vessels, and wood; he also found that, in the Grasses and Palms, the younger leaves were supplied by the outer, the older by the inner vascular bundles. (Beiträge, p. 50.)

Thus far, therefore, our researches fully accord; but they differ in many points in respect to the fibrous bundles devoid of vessels, and the origin of the wood, the reason of which doubtless lies in the fact, that Moldenhawer

neglected to examine the same vascular bundle in various parts of its course, so that its changes of form and structure remained unknown to him. Moldenhawer states that both in the Grasses and the Palms, fibrous bundles without vessels are formed beneath the rind, and believed that shortly after their formation proper vessels, and subsequently the wood portion, were deposited on their inner side, and that in this way the fibrous bundles became vascular bundles. I cannot confirm this account, for the transition from the evascular fibrous bundle into the vascular bundle is merely one relating to space, and has no reference to its development in time; the lower part of every vascular bundle remains permanently in the condition of an evascular bundle of prosenchymatous cells, while its upper portion does not appear, even in its earliest stage, in the form of a liber-bundle; but even at a period when it is still of a gelatinous delicacy of consistence, the rudiments of all the parts which it subsequently contains may be detected in it.

Moldenhawer further states, that in the Palms, not only has each vascular bundle its proper liber, but there exists besides a general liber, lying under the rind (l. c. p. 56). There is found, he says, in *Phœnix* and other Palms, a line of separation between the wood-layer and the rind, from which those fibrous bundles develope inwards, which are changed into vascular bundles, but on its outside, those which contain only fibrous cells, the latter being comparable to the liber of trees. A correctly observed fact certainly appears to afford the ground for this opinion. I have observed already, that in many Palms, especially in the *Cocos*-like stems, the rind becomes gradually thickened, and this in an irregular manner; that larger or smaller portions of the cellular tissue in which the fibrous bundles are imbedded acquire thickness in their walls, and form a firm, apparently dead envelope. In this change of the outer parts of the fibrous layer, the newly-developing fibres cannot be produced on the outside of the older; they must, therefore, originate in the interior of the fibrous layer, and the matter may thus acquire some resemblance to the formation of liber in the Dicotyledons. But a second circumstance also has to be considered, which might have contributed still more readily to render Moldenhawer's opinion, that the Palms possess a general liber, plausible. In those species, namely, where, as in *Cocos*, the outer fibrous layer is very thick, in tracing their evascular fibrous bundles, it is found that they do not all enter into the interior of the stem, and become converted into vascular bundles, but that a portion of them pass immediately into the petiole. But as those fibrous bundles are changed, like the rest, into vascular bundles in the petiole, they cannot be regarded as liber-bundles corresponding to the liber of the Dicotyledons.

2. Another circumstance remains to be mentioned, occurring in many Palms, and which at first sight does not appear to harmonize with the theories of their growth detailed above. We find in many Palms, that their evascular, small, fibrous bundles do not all lie between the rind and the developed

vascular bundles, but some of them are met with scattered among the vascular bundles of the stem, for example, in *Astrocaryum vulgare*, *Cocos botryophora*, *coronata*, *Leopoldinia pulchra*. I have met with this modification principally in the *Cocos*-like stems, in others only in rare cases. These fibres, therefore, only occur in such stems as possess a fibrous layer abundantly furnished with fibres, and a great many vascular bundles. Consequently it is probable, that in the great mass of closely-crowded bundles which fill up these stems, circumstances readily arise, which prevent the nascent fibres from becoming developed in the normal positions, and give rise to their origin in unusual places. These scattered fibres, too, do not seem to occur in all specimens of the same species, at least they were very abundant in one stem of *Leopoldinia pulchra*, while in a second they were altogether wanting, which evidently proves that accidental causes give occasion to their origin.

3. Mirbel fell into still greater error than Moldenhawer in his researches into the course of development of the vascular bundles of the Monocotyledons. He states (Annal. du Muséum, xiii, 69) that each vascular bundle is formed, at its origin, solely of one bundle of large ducts (reticulated vessels), that around these a tissue of delicate tubes is gradually formed, by which is understood the cellular tissue of the wood, the spiral vessels, annular vessels, the proper vessels, and the liber-bundle, these parts not being distinguished. The membrane of these tubes, then, gradually becomes so much thickened that at length their cavities are filled up.

4. In a description of the vascular bundle of *Calamus* (Ann. d. Sc. nat. ii, pp. 229-236), Amici attributes a different import to the different parts of the vascular bundle from that which I have done. Amici considers the wood-cells to be liber-tubes, the liber-tubes proper vessels, the proper vessels he indeed recognises as thin-walled and not porous tubes, but leaves it undetermined to what kind of organ they belong. The description and representation of the vascular bundles of *Calamus*, given by Kieser (Phytot. p. 121, Tab. iii, fig. 29), deviates still more from the truth, since the liber- and wood-layers are not distinguished at all, and the proper vessels are regarded as spiral vessels.

5. I shall readily be excused from detailing minutely the views of Lestiboudois; he believes that the Palm-stem is to be compared with the bark of the Dicotyledons, he finds nothing analogous to wood and pith. (Principes de Botanique, pp. 149-158.) This strikingly testifies how little he is acquainted with the minute anatomy of plants.

OF THE ROOT OF THE PALMS.

Form of the Root.

The full-grown Palm-stem is never furnished with a tap-root, but its inferior portion, rounded off like a bulb, is clothed with a quantity of fibrous, branching roots. These roots are always slender, not very long, beset in an irregular manner with slender lateral branches, cylindrical, obtuse at the extremities, in the young condition white, and subsequently brownish. Their young shoots are clothed with fine hairs; sometimes short spinous elevations occur on the root, which are to be regarded as abortive lateral branches. The germinating Palm has a tap-root, but this attains no considerable size. Shortly after germination, side roots are developed from the base of the stem; the tap-root disappears, and after a time the first side roots also die away, and are replaced by new rootlets, which spring out in a circle above the earlier ones. This process is repeated in a manner analogous to that in the bulbous plants. Although the roots arise very closely crowded together, yet the subterraneous portion of the stem soon becomes completely covered with roots, and the new ones then arise, as in *Pandanus*, above ground. In this way it often happens that the stem stands raised free above the surface of the earth, merely supported by the roots; for example, in *Iriartea exorhiza*.

The formation and first development of the roots occur in the interior of the stem, between the fibrous layer and the developed vascular bundles. In this place is formed a nucleus of cellular tissue (a true bud), which acquires the shape of a root, and breaks through the rind. Such buds of future roots may be found in considerable abun-

dance for the distance of some inches above the youngest circle of roots, when the bark and fibrous layer are cut open down to the vascular bundles.

Anatomical Examination of the Root.

The Palm-root is composed of two distinctly separated layers—an outer, looser, and spongy cortical substance, and a tough, woody, central bundle.

The cortical substance is coated by a parchment-like membrane, under which lies a white spongy mass, in which in some species lie liberous fibres; in others these are wholly wanting. Toward the extremity of the root, and in the young side roots, this cortical layer is succulent and compact; in the older parts of the root it is often half dried and more lax. The central bundle is formed of a compact woody substance, which cannot be separated into distinct individual bundles like the wood of the stem. The central bundle of the side roots is immediately connected with that of the main roots.

When a root is traced backwards into the stem, it is found that the cortical part of the root is considerably diminished at its entrance into the cortical layer of the stem, after a short distance disappearing by blending with the cellular tissue of the stem. The central bundle, on the contrary, penetrates the fibrous layer of the stem, and spreads out on the outer layers of the wood-bundles of the latter in the form of a disk. In its way through the fibrous layer, it already begins to divide into several bundles, separated by thin layers of cellular tissue. When it arrives at the woody layer of the stem, it divides into a great number of delicate filamentous bundles, which run out in all directions like the rays of a star, and, passing in serpentine course between the vascular bundles of the stem, enter into its interior. They cannot be traced more than about half an inch down between the woody bundles, because they continually divide into

successively finer portions, apply themselves upon the vascular bundles of the stem, and there terminate.

Besides this connexion with the interior of the stem, the root is most intimately connected with fibrous layer by means of its cortical portion; for, into the cortical portion of each root penetrates a portion of the evascular fibrous bundles of the stem. In some roots, as in those of *Cocos* and *Phœnix*, the little fibrous bundles run still further out into the roots, and then lose themselves gradually; in others, as in *Diplothemium maritimum*, *Sabal Adansonii*, they are at once lost at the very beginning of the root.

In *Dracæna Draco*, also, I observed that the outer, fibrous, firm layer of the stem penetrated the roots, was continued some distance in this, and formed a sheath round its central body, which was far stronger and longer on the side turned towards the surface of the earth than on the under. This fibrous layer was gradually attenuated, and altogether lost in the distance of a few inches. It is clear from this, that the opinion of Dupetit-Thouars, that the roots are formed of the fibres running down from the leaves and buds, is totally erroneous.

The roots of different Palms possess a very similar organization. That of *Diplothemium maritimum* may serve as an example. In the cross section, it is seen that in the central bundle all the vessels lie toward the circumference, and the middle is, formed solely of cells. The vessels are constantly placed in such a manner that the largest are nearest the centre, the smallest nearest the circumference; therefore the condition is the contrary of that which we have met with in the stem. The vessels do not lie, as in the vascular bundles of the stem, irregularly scattered and isolated, but in rows, which are directed from the centre toward the circumference, and these rows are frequently split toward the exterior into two diverging arms. The largest of these vessels present the form of reticulated vessels, and are composed of rather short tubes, possessing reticularly perforated septa at their ends. The small vessels, situated more externally, exhibit the form of porous and scalariform ducts. In

respect to the epoch of their development, the latter agree with the spiral vessels of the vascular bundle of the stem, for they are already completely formed at a time when the large vessels still appear as thin-walled tubes without fibrous deposits, and the cells of the root have yet but extremely delicate membranes. The vessels are surrounded by rather thick-walled, much elongated cells, with horizontal septa. But only those cells situated next to the vessels exhibit these horizontal septa, and they pass, in the interspaces between the vessels and in the central space inclosed by the vessels, into prosenchymatous cells, which, in the centre of the vascular bundle, are again transformed into elongated parenchyma, and form an analogue to the pith. The whole central body is surrounded at its circumference by a few layers of thin-walled prosenchymatous cells, to which follows a row of narrow, elongated thick-walled cells.

Between every two groups of vessels lies a bundle of proper vessels; the size of this is ruled by the length of the rows of vessels lying beside it, for only a small roundish bundle lies between the short rows, while those situated between the long rows extend far in toward the centre of the root. The arrangement of the proper vessels is always such, that those lying internally are very wide, the outer very narrow: the narrower and wider are not, as in the stem, mingled together. The membranes of these vessels are always thin, not unfrequently finely porous, which also sometimes occurs in those of the stem of *Tamus elephantipes*. They are composed, both the wide and narrow, of closed elongated tubes, with horizontal or diagonal septa; like those of the stem, they contain an opaque, granular sap.

The cortical substance consists chiefly of regular thin-walled parenchyma-cells, with intercellular passages. Those cells in the vicinity of the vascular bundle have no intercellular passages between them, and are somewhat expanded in the direction of their breadth. The intercellular passages also disappear toward the surface of the

rind; the cells become larger; the outer, at the same time, acquire thickness in their walls, and form the coriaceous membrane above described. The epidermis is composed of cells not elongated, but papilliform and projecting. In the young root the rind is compact; but with the greater expansion of the root in thickness, and the decrease of its juices, the cells separate from each other in isolated, larger or smaller, irregularly scattered places, and thus form irregularly distributed air-cavities. The cells immediately surrounding the central body, contain on their inner side transverse fibrous thickenings, like many anther-cells. Isolated cells, scattered without order in the rind, contain raphides.

The lateral roots spring from the larger roots in the same way as these do from the stem. A nucleus of cellular tissue is formed between the rind and central body of the main root, and in this are developed moniliform vessels. On further enlargement, this nucleus breaks through the rind of the root, and appears as a branch of it. The moniliform vessels penetrate the central body of the root, run in the most varied directions in the cellular tissue situated between the vessels, and finally apply themselves to the sides of the large vessels. In the lateral root itself, the vascular tubes become more and more elongated, and form, with a portion of the cellular tissue which they inclose, and with the elongated cells by which they are surrounded, the central body of the root-branch. The most external layer of these elongated cells is blended with the thick-walled cells surrounding the central body of the main root; while the more central, pith-like cells of the lateral root are connected with the parenchyma situated beneath these elongated cells. The rind of the side root is, indeed, separated from these in the greater part of its course through the rind of the main root, by its epidermis and its outer layer of elongated cells; but both the elongated and the parenchymatous cells of the rind of the side root are blended with the more internal layers of the rind of the main root.

The connexion of the root with the stem takes place in a manner wholly analogous; since in this also, in the dissolution of the central body into single fibres, its vessels are distributed into a great number of fine moniliform vessels. Those fibres penetrating the stem are, indeed, formed for the most part of thin moniliform vessels; but they nevertheless present an organization tolerably resembling that of the vascular bundle of the stem, for their vessels are surrounded by cellular tissue, a little liber-bundle lies upon their outer side, and their proper vessels occur between this liber-bundle and the wood.

I found the structure described, perfectly similar in the roots of a considerable number of Palms, as might indeed be expected, since the said structure occurs almost as universally in the roots of Monocotyledons as the above-described structure of the vascular bundles in their stems.

This structure, however, is not without exceptions. I have already said that in the upper parts of many Palm-roots, e. g. *Phœnix*, *Cocos*, fibrous bundles are scattered through the rind, while no trace of them is found in others. But the rather thick root of *Iriartea exorhiza* exhibits more important deviations. A cross section of it presents to the naked eye a star composed of brown lines, with obtuse, mostly bifid, rays. The microscope shows that this star is formed of crowded vascular bundles. Besides these, scattered vascular bundles occur singly in the centre of the star, but a central cord, like that in the other Palm-roots, is wanting. The vascular bundles have a structure totally unlike that of the vascular bundles of the stem, the relative position of their organic systems being quite different. The liber-bundle is directed towards the centre of the root, and in some of the vascular bundles lying in the middle of the root, surrounds the woody portion. The liber-tubes have thicker walls, and are more numerous in the outer bundles than in those situated in the middle. The woody portion has 1, in rare cases 2-3 large vessels, which in the outer bundles are $\frac{1}{25}$-$\frac{1}{17}$, in the inner, $\frac{1}{77}$-$\frac{1}{12}$ of a line in diameter. They are composed of longish tubes, some have horizontal septa, some are without these; their walls are covered with little pores, placed in longitudinal rows; where two vessels are in contact, they have the form of scalariform ducts. They are surrounded merely by 1-2 rows of parenchymatous cells. The outer side of this woody portion is in contact with the parenchyma of the root. The bundles of proper vessels, of which each vascular bundle contains one or two groups, consist, as in the stem, of mingled, wide and narrow tubes. These do not lie between the wood and liber, but in most cases on the outside of the liber-layer, half

imbedded in it; in the inner vascular bundles, the proper vessels are sometimes wholly surrounded by the liber-tubes. The outer vascular bundles are often confluent in pairs, in which case the compound bundle possesses four groups of proper vessels, or, from the confluence of one pair, frequently only three.

The parenchyma of the root consists of thin-walled, somewhat elongated, porous, parenchymatous cells, which in many places leave irregular spaces between them. Around the stars formed by the vascular bundles, separated from them by a few rows of cells, runs a darkish line, formed by cells with rather thicker walls. Scattered through the whole root, and accumulated in especial quantity in its outer layers, lie evascular, fibrous bundles, the outer of which are often blended together, and are composed of thick-walled, prosenchymatous cells; in the middle of those situated more internally, occur from one to two thin-walled cells, which probably belong to the system of proper vessels. I can state nothing concerning the connexion of these fibrous bundles with the stem, as I had no opportunity of examining the latter. These roots of *Iriartea* are clothed with short thorns, which are to be looked upon as abortive lateral branches, and have their origin from the vascular bundles of the main roots.

Different as this root appears to be from those of other Palms, yet it is clear that its organization agrees with that of the latter in many respects, since most of the characters by which the vascular bundles of the roots are distinguished from those of the stem, occur in the root of *Iriartea*, as well as in the roots of other Palms. The reversed position, which is exhibited by the vascular bundles of the roots of *Iriartea*, corresponds to the circumstance met with in other Palm-roots, that the cells lying behind their vessels likewise have the form of prosenchymatous cells. In both varieties of the root the large vessels lie furthest inward, the small ones externally; in both, the proper vessels form special bundles not inclosed between the wood and liber.

APPENDIX.

It will not be unfitting to append to the preceding description of the Palm-stem, a short account of the works on this subject, which have appeared since it was first published.*

* My purpose here is not an enumeration of all the observations on this subject which have appeared since my Anatomy of Palms, but only an

Pre-eminently deserving of mention is the acute Essay of Meneghini (*Ricerche sulla Struttura del Caule nelle Piante Monocotiledoni*, Padova, 1836), in which the structure of the stem of Monocotyledons is traced in its various forms, and described with great clearness. So far as this exposition relates to the arborescent Monocotyledons, the following points might indeed be brought forward in opposition to my description. Meneghini, who, in his description of the course of the vascular bundle, traces it as I did from above downwards, devotes especial attention to the changes which its position undergoes during the development of the terminal bud into stem, and, in reference to this, lays particular stress upon the circumstance that, so long as the leaves remain inclosed in the bud, only that part of the vascular bundle exists, which in the full-grown bundle runs from the middle of the stem downwards and outwards, and that its upper portion is first developed with the development of the bud into stem, and with the emergence of the leaves from the centre of the bud out to the lateral surface of the stem. From this passage outward of the leaf from the centre of the bud, is derived the curve of the vascular bundle in the centre of the stem, and the outward direction of the course of the upper part of the vascular bundle. Meneghini paid especial attention to the examination of the circumstance that the vascular bundles present, not only this curve outward, but at the same time a lateral bend, so that their lower extremity does not lie in a perpendicular direction beneath the upper end, but diverges to its left or right. I also had observed this circumstance in the Palm-stems I investigated, but attached no importance to it, as I considered the oblique course of the fibres an accidental deviation.

examination of such works as have had an influence on the progress of the study of the structure of the stem of Monocotyledons, and especially of the Palms, whether by the announcement of new, hitherto unnoticed facts, or by the extension of the study in its theoretical aspect; I therefore shall pass over, in particular, Gaudichaud's works, since the researches on which his theory rests, have too much the stamp of superficiality to allow me to expect any profit from them to the study of the structure of plants.

Meneghini has shown, on the contrary, that this condition occurs in all Monocotyledons; for the elucidation of this he did not select Palms, but principally the stems of *Dracæna*, *Aletris*, and *Yucca*, in which, however, if his theory be correct, the oblique course of the fibres deviates materially from that occurring in the Palms. In order to give a review of the opinion promulgated by Meneghini, an examination of his investigation of *Dracæna* and the allied forms is necessary. Meneghini states, in regard to *Dracæna Draco*, that no fibre of its stem runs vertically, but that the upper part proceeds inward in the direction of a radius, toward the centre of the stem; near this it turns downwards, and at the same time to the right or left, and then runs obliquely downwards and outwards, so that its inferior extremity lies beneath the surface of the stem, to the right or to the left of the upper end. Perhaps no two vascular bundles of the same leaf exhibit the same course, for some penetrate almost to the centre of the stem before they turn downwards, others acquire a curve at a short distance from the rind, some deviating to the right, others to the left of the perpendicular line.

The changes which the leaf undergoes during its development are regarded as the cause of this oblique course of the fibres. As the adoption of this point of view by Meneghini is wholly peculiar, and forms the most essential part of his doctrine of the structure of the Monocotyledonous stem, we must enter somewhat more minutely into it. Meneghini assumes that, in all the Monocotyledons, the leaf originates in the form of a closed, reversed funnel, which subsequently becomes torn up along one side, either the whole way or only at its upper part, by the pressure of the younger leaves succeeding it in the interior. When only the upper portion is torn, the lower part forms the sheath of the leaf, and the leaf remains perfectly amplexicaul; in the other case, the relation of the base of the leaf to the circumference of the stem does not necessarily remain the same in its further development, but the stem usually grows, proportionately, more in thickness, than the base

of the leaf in breadth, and thus the leaf occupies so much the smaller arc of the circumference of the stem, the older the latter grows; while in other cases, the converse may take place, the leaf grow broader than the stem, and the two borders of the leaf overlap. As examples of such plants, in which the originally perfectly amplexicaul leaf only partly embraces the stem when full-grown, *Aletris fragrans* and *Dracæna Draco* are, in particular, brought forward; in the former, the full-grown leaf embraces $\frac{5}{8}$ of the stem, in the latter, the leaves at the apex of the yearling-shoot are still perfectly amplexicaul, while on older stems the cicatrices of the leaves only extend $\frac{1}{3}$ round the stem. This proportionately greater expansion of the stem in thickness is connected, in *Dracæna*, with an abbreviation of the already perfectly formed internodes, as is apparent in a comparison of the length of the internodes of the yearling-shoot with those of the old stem, and as even a superficial examination of the growth of *Dracæna* shows; for the rapid growth of the yearling-shoot does not by any means correspond to a proportionate elongation of the whole plant (p. 22). A necessary consequence of this change of the relative proportion of the breadth of the leaf to the thickness of the stem is, a change of the original position of the vascular bundles in the interior of the stem. So long as the young leaf surrounds the stem and lies in the middle of the bud, the vascular bundles (corresponding to the lower portions of the complete vascular bundles) run from the whole periphery of the stem, in a radial direction, towards the base of the leaf. As the bud unfolds, the internode perfected beneath the leaf to which it belongs, and the leaf proceeds outwards from the centre of the bud towards the periphery of the stem, the upper portions of the vascular bundles are developed, which, in consequence of this outward movement of the leaf, assume a curve from the centre of the stem towards the exterior, and run out in the direction of a radius. Since, however, during the completion of the leaf, the proportion of its breadth to

the circumference of the stem diminishes, the upper part of the vascular bundles must also follow the leaf, and, therefore, those vascular bundles which enter the sides of the leaf, instead of being directed in a radial direction to all sides of the stem, as in the perfectly amplexicaul leaf, are only curved towards the arc of the circumference of the stem, on which the leaf is inserted, and since the lower part of each vascular bundle retains its position more or less unchanged, the result is the described condition of a double curvature, downwards and to the side. The greater the difference between the circumference of the stem and the breadth of the base of the leaf, the shorter the internodes, the greater must be this divergence; hence it is greater in *Dracæna* than in *Yucca*, in *Yucca* it is greater than in *Aletris*.

Before I go further into the detail of Meneghini's theory, it will be advantageous to test the facts on which it rests. In this I pass over the question whether the leaves do originate under the form of closed funnels, or not, as this has no essential influence on the theory. The only essential question is, whether or not the breadth of the base of the leaf does gradually diminish its proportion to the circumference of the stem with the age of the latter. That such a change must lead to the alteration in the course of the vascular bundle which Meneghini has deduced from it, does not admit of a doubt; at all events, if it be presupposed that at the time when this change takes place, the vascular bundles running to the younger leaves, which cross those of the leaf that has begun to change its position, do not oppose any hinderance to the movement of the latter. I believe that this certainly must be the case, and this circumstance alone already makes the theory of the Paduan phytotomist appear untenable; if, however, we even overlook this, there exist other, more definite reasons, which show that the unequal growth of the leaf and the circumference of the stem do not occur in the way Meneghini has represented. According to his statements, this process is most clearly to be seen in *Dracæna Draco*, for the leaves, or their

cicatrices, embrace a smaller portion of the circumference of the stem, in proportion as they are situated lower down upon it, so that the cicatrices only occupy a third of the lower part of the stem, while the leaves at the summit of the yearling-shoot completely surround it.

I can only confirm the smallest possible part of this statement. I decidedly found no change of the relative position and size of the cicatrices, in the stems which I examined in reference to Meneghini's statements, (the largest being about twenty-seven feet high, and thirty-seven centimeters in circumference at the lower part), but the scars of the leaves just fallen exhibited the same proportion to the circumference of the stem as the scars at the lower part of the stem, i. e. they extended round about $\frac{2}{3}$ to $\frac{3}{5}$ of the stem. Measurements, which I instituted on different cicatrices, showed that small variations occur in the proportion of the breadth of the scar to the circumference of the stem, which are not at all connected with the age of the stem. Removal of the leaves from the terminal bud showed, that not only is the same proportion of the base of the leaf to the circumference of the stem to be found in the leaves which are seated on the conical portion of the stem, concealed in the leaf-bud, but that it also holds for those leaves situated on the upper, flattened surface of the axis of the bud, excepting the innermost. As, on the other hand, continuing the removal of the leaves, we approach the youngest leaflets, this proportion alters, for the borders now certainly do approach each other. In one bud I examined, the borders of the innermost leaflet in which the lamina was distinctly formed, were approached to within $\frac{1}{6}$ of the circumference of the circle; the next leaflet appeared in the form of a perfectly amplexicaul cone, about one millimeter in diameter, at the base of which was to be seen a narrow, short slit; it had exactly the form of the cotyledon of a Monocotyledonous embryo; in the succeeding leaflet, the slit formed by the borders of the leaf was again more widely opened. This observation does indeed fully con-

firm the assumption of Meneghini, that in *Dracæna Draco* the perfectly amplexicaul leaf is changed into one which does not surround the stem, but an essential distinction exists, in that Meneghini states this change to begin after the completion of the leaf, and to be continued further in the cicatrix after the fall of the leaf; while the result of my investigation is, that the leaf only surrounds the stem so long as the part of the axis of the bud on which it is inserted is still in a rudimentary condition, and the thickness has not, or scarcely, exceeded a millimeter; that in the next older leaflet the borders are already $\frac{1}{6}$ of the circumference of the stem apart, and the permanent proportion between the base of the leaf and the circumference of the stem already exists in the leaflets situated but a couple of internodes further out. This difference in the results of our investigations is very much the more important, as will be shown further on, in so far that such an alteration of the proportion of the breadth of the base of the leaf and the circumference of the developed stem must cause extraordinarily great changes, which we never see, in the internal structure of the stem, and in its growth in thickness; while such changes, if they begin in a portion of the stem a millimeter thick, and cease in a part only a few millimeters in diameter, take place in a part which consists merely of soft cellular tissue in full process of multiplication, which exhibits extremely rapid growth in all its parts, in which, therefore, the softness and continual metamorphosis of its substance, present no mechanical hinderance to a more rapid development of one part, and a less extensive development of another. That these changes of form exert influence on the lateral divergence of the vascular bundles cannot, indeed, be denied; but, on the other hand I cannot think, that they are the sole, or even the principal cause of their oblique course, inasmuch as this occurs in the vascular bundles of *Aletris fragrans*, although no trace of an alteration of proportion between the base of the leaf and the circumference of the stem is to be discovered here.

According to Meneghini's statements, the borders of the leaves should here also separate so far, that the cicatrix only surrounds $\frac{2}{3}$ of the stem; but I cannot give the least confirmation to this statement. The borders of the leaf overlap a little at the base; this condition is no longer visible on the cicatrix after the leaf has fallen, for this appears simply encircling the stem. However, this peculiarity is exhibited not merely by the young stems, from which the leaves have newly fallen, but also by old stems; and, in particular, on a stem thirty-eight centimeters in circumference, in the Tübingen Garden, the leaf-scars are perfectly evident, and still exactly surround the stem, although, from the great increase in thickness, its rind presents many longitudinal fissures. Consequently, observation of the surface of the stem, decidedly does not confirm Meneghini's view as to the alteration of the leaf of *Aletris*, and the subsequent changes in *Dracæna;* and the matter might here have been regarded as settled, but that the objection that in other specimens than those which I have examined, the conditions might exist such as my honoured friend has described, rendered it to the purpose, to institute a more minute examination of the changes which a stem would necessarily undergo, the circumference of which became more enlarged than the bases of the leaves, in the way described, after its leaves were perfectly formed or had fallen, since this examination will show that this process cannot possibly present itself in stems with abbreviated internodes. I have before me a portion of a stem of *Aletris fragrans* 31 inches long; at the upper end it is 10·5 lines in diameter, at the lower 13 lines; the external, hard, fibrous layer is 1 line thick above, 2·5 lines thick below: there are upon it 57 leaf-scars, hence an internode is, on an average, 6·5 lines long. The cicatrices surround the stem, and are placed obliquely, in such a way, that one part of each of them, corresponding to the middle line of the leaf, is lower down than the opposite part corresponding to the borders of the leaf; so that

in each case the point of insertion of the borders of a leaf is approximated to within about three lines of the point of insertion of the central portion of the leaf next above it. If, now, we imagine the lowest internode to expand so much in breadth (without enlargement of the cicatrix), that the meeting borders of the cicatrix would be separated about ½ of the breadth of the cicatrix, a portion of stem, nearly eight lines in breadth, must be inserted between the separating borders of the leaf; and during the period of the completion of the structure of this piece of stem, new tissue must be formed in the interior; the firm, fibrous layer, already 2·5 lines thick, must enlarge a fifth part of its circumference; and the inner soft substances must increase in quantity, in like proportion, to fill up the space within this expanded layer. Of all this, no trace can be found in the examination of a stem of *Aletris*. Instead of what this theory requires, the insertion of an entire segment of a circle between the old parts, and the enlargement of the internal soft substance, we find that the latter, when once formed, remains for ever unchanged, and in like manner no new development is met with, in any part of the substance, of firm woody layers; but we do find that new fibres and cells are produced uniformly in a true cambium layer around it, and upon its outside. This stationary condition of the internal parts of the stem, is again, fully sufficient of itself to refute the whole of Meneghini's theory. But if, disregarding this fact, we imagine the lowest internode, the cicatrix of which in the stem under consideration was 39 lines in circumference, to undergo the change described, this would obtain, by the addition of ½ of the size of the base of the leaf, a circumference of 47 lines. In this expansion the next internode above must share, since we always find the stem of *Aletris* to be nearly cylindrical. But the part of the leaf next above, which lies only a couple of lines to one side, is situated only about three lines above the borders of the lowest leaf, from which we set out.

With such a short distance between the lower and upper leaf, the expansion of the lower internode must be continued into the part of the upper leaf which stands vertically above the growing portion of the lower internode; since the fibres, which would form the piece of stem inserted between the borders of the leaf of the lower internode, must, like all other fibres of the plant, be continued in a tolerably straight direction upwards in the stem; hence the cicatrix of the second leaf must become wider. The second cicatrix, in the stem in question, is likewise 39 lines broad, but we must add about eight lines for the expansion of the lower internode; therefore, we obtain 47 lines as its breadth. If we next suppose, in accordance with Meneghini, the growth in like manner of a piece $\frac{1}{5}$ of the breadth of the leaf between the borders of the leaf of of the second internode, the circumference of this internode would be increased at least nine lines, and we thus obtain a circuit of 56 lines. This internode would, consequently, exceed the lower about nine lines in circumference. Since we do not find this in nature, and since we must assume that the fibres which grow between the borders of the leaf of the second internode must be continuous into the lower internode, we are compelled to assume that the lower internode shares in the expansion of the upper, and, consequently, also acquires a circumference of 56 lines. But if, now, that which occurred in the second leaf hold also exactly for the third, its middle portion must expand about nine lines in breadth, because a piece of stem equal to one sixth of 56 has grown beneath it, in the internode of the second leaf. The breadth of the second leaf amounted to 47 lines; the third would, therefore, be 56 lines broad. Then allowing the borders of the leaf to separate about $\frac{1}{5}$ of the breadth of it, we obtain 67 lines for the circumference of the internode. In this enlargement, the lower internodes again naturally take part; we have, therefore, raised the circumference of the stem from 39 to 67 lines by these changes of only three internodes, and yet we are still far below

the size which the stem must acquire, since this expansion of the lower internodes would again be followed by an expansion of their cicatrices in breadth, which would again necessitate an increased expansion of the part of the stem lying between the borders of the leaves (for this part should equal $\frac{1}{3}$ of the cicatrix); and in consequence of this, the upper leaves would be again expanded in breadth, which expansion would react again upon the lower internode, and so on. It is easy to see that this cannot be the proceeding which nature follows in the growth of these stems, since it would lead to an immense increase of thickness, even if it were restricted to a condition where the margins of the leaves were separated about $\frac{1}{3}$ of the breadth of the leaf at the complete development of the latter; and that in *Dracæna*, where the separation of the margins of the leaves would equal double the breadth of the latter, the increase of the diameter of the stem must occur in a far more excessive proportion. Since, therefore, on the one hand, these conclusions, which are necessary deductions from the processes asserted by Meneghini to occur, would lead to impossibility, and, on the other hand, both direct observation of the cicatrices and the anatomical examination of the stem testify most clearly against this notion of an unequal growth of the leaf-scars and the circumference of the stem, the divergence of the fibres from the perpendicular line cannot be caused by the mechanical process supposed by Meneghini.

Even if this oblique direction of the fibres were a consequence of the unequal growth of the leaf-scar and the circumference of the stem in *Dracæna*, *Aletris*, &c., this derivation of it would not be applicable to the Palm-stem, since this always has its leaves and leaf-scars surrounding the stem. Meneghini did not overlook this circumstance; but he imagined he had discovered a second mechanical cause, which produced an oblique position of the fibres also in the stems with completely amplexicaul leaves, and which consisted in a movement of the leaves to one side.

He starts from the fact, that the leaves of the arborescent Monocotyledons, e. g. of *Yucca*, lie in a heliacal line, which in the flattened bud of these plants passes into a true spiral. The heliacal line marks a constant relation; this does not exist in the spiral, for this passes, with the further development of the leaves lying in it, and the conversion of the bud into stem, into the heliacal line running upon the side of the stem; in this, the same lines still remain, since they always gain at their inner end as much as they lose at their outer end by passing into the form of a helix. Each leaf originates in the centre of the bud, and passes, when a new leaf arises in the centre, into the place of the preceding one, till at last it comes to be situated on the outer surface of the stem. In this movement each leaf follows a spiral course, in which the mutual relations of the leaves remain the same, and all the leaves are carried back uniformly. Each leaf therefore exhibits, besides the movement from within towards the outside, and from above downwards, also a horizontal motion in a spiral direction; on the first of these motions depends the divergence of the vascular bundle from the vertical line; the second gives rise to a divergence in the horizontal direction, since the upper part of the vascular bundle, running from the centre of the stem to the leaf, follows the lateral motion of the latter. Since the turns of the spiral are closer in the middle, and the motion of the leaves becomes slower in proportion as they pass further out, the greatest bending of the vascular bundles takes place in the centre of the stem (l. c. p. 16.)

Against the idea that, in the development of the terminal bud into stem, the leaf-spiral passes into a helix, and that each leaf traverses the length of this spiral, no objection can be urged; this traverse of the spiral, however, is only a seeming movement, and by no means connected with an actual motion to the side. If Meneghini's idea were correct, it is clear that the most external leaf seated on the spiral, could not advance with it in a lateral

movement towards the surface of the stem, without the divergence between it and the uppermost leaf upon the helix becoming diminished, until the leaf had arrived at the lateral surface of the stem, and there become permanently fixed. It is equally clear that if the rest of the leaves should follow this first at uniform distances, from the turns of the spiral being closer towards the interior, the divergence between the successive leaves would increase in proportion as they were situated more internally, and would first acquire the dimension normal for the species at the transit of these leaves over on to the heliacal line. On the other side it is likewise evident that, without any alteration of their divergence, the leaves would seem to traverse a spiral, if each of them proceeded towards the periphery upon the radius on which it stands at its first origin; for during the expansion of the axis of the bud, its most external part extends outwards and upwards to become the surface of the stem, the outer end of the spiral running upon this part of the axis, passes, as a continuation of the helix, on to the outer surface of the stem, and the succeeding leaf advances just so much nearer to the end of the spiral line, not because it makes a lateral movement upon it, but because the spiral line is abbreviated in the direction towards the leaf, and its point of transition into the helix advances nearer to the point at which the radius, on which the leaf stands, intersects the circumference of the stem. Which of these processes occurs, whether the leaf actually advances laterally, or the motion is only apparent, may be decided by investigation whether or not the divergence of the leaves alters. Now I believe that it will be found on examination of the position of the leaves, that they exhibit the same divergence in the terminal bud as on the stem, and that the arrangement of the leaves passes with uniform divergence from the helix into the spiral, and is continued in this; while, according to Meneghini's idea, the divergence must increase in the spiral. The distance from a leaf to its successor on the spiral will naturally be

shorter, looking at its absolute size, the nearer it is to the inner end, but the angular divergence of the leaves will be the same. If this be the case, and I believe that all investigations hitherto made testify that such is the condition, it is evident that the movement of every leaf takes place in the radial direction, and is simply a consequence of the elongation and expansion of the axis; that the motion of any leaf in a spiral direction is only apparent, and results from the fact that the spiral line has no definite place upon the upper surface of the bud, but its point of origin continually advances in the direction in which the leaf-spiral runs, into the circle which is formed by the connexion of the cylindrical surface of the stem with the depressed surface of the bud. If such be the condition, the leaves must appear to traverse the outer turns of the spiral more rapidly than the inner, since the same angles of divergence correspond to larger segments of turns in the outer parts of the spiral, while, according to Meneghini's theory, the contrary occurs: the motion of the leaves diminishes in regard to the angle of divergence in the outer turns of the spiral, but in regard to the spaces passed through remains the same, and thus must appear to become slower. Since, although I had investigated the terminal buds of some large Monocotyledonous plants in reference to this point, and had found no notable deviation with regard to the divergence of their leaves, my judgment on this matter could not be nearly so valuable as that of my honoured friend, Professor Alexander Braun, I wrote to ask him whether he had ever met with cases of such a deviation in the divergence in the terminal bud as is required by Meneghini's theory, and obtained the answer, that he is indeed of opinion that it is very difficult to settle this point with certainty by direct observation, but from his own researches, he believes the divergence in the terminal bud to be the same as in the stem. From this important confirmation of my views, it appears to me that the entire doctrine of an actual spiral motion of the leaves, and the deduction from it of the oblique

direction of the fibres, must be thrown aside. There are still further reasons against Meneghini's asserted lateral motion of the leaves. If the oblique direction of the fibres were caused by such a motion, it is evident that all the fibres ought to run in the same direction (right or left), since this movement of the leaves must have the same effect as a twisting of the stem. Therefore, if a Palm-stem be split longitudinally, the split surface ought to follow that spiral in which the fibres run in the stem, and no fibres should be torn by such a splitting, as they would all be homodromously curved in their course downwards from the centre of the stem. I investigated this condition in a stem of the Brazilian Palm, which has lately been imported for manufacturing purposes, in lengths of about seven inches. The split surfaces of this stem never run in an oblique direction, but always parallel with the axis, and a considerable resistance is offered in the process of splitting, since, in the split, not only are fibres running parallel separated, but a very great number of the fibres of the stem must be torn across, because one portion of the fibres runs obliquely through the stem from right to left, and another in the opposite direction. Thus, in reference to this oblique direction of the fibres, exactly the same condition occurs in the Palms as in *Dracæna*, *Yucca*, and still more evidently in *Xanthorrhœa*, in which the fibres running right and left lie in alternating layers surrounding the stem, exhibiting in the cross section some resemblance to the annual rings of a Dicotyledonous stem.

It is sufficiently shown by the preceding observations, that the explanation given by Meneghini of the oblique course of the vascular bundles cannot be correct, either in *Dracæna*, or in the stems which have amplexicaul leaves; we must seek the reason of it, not in mechanical causes, but in the organic activity of the plant.

In reference to the vascular bundles of the root, Meneghini observed that in a young *Chamærops* they passed directly into the vascular bundles of the leaves; but that in the roots breaking through higher up on an

old stem, the condition was different, the greater number of their vascular bundles being lost in the outer woody layers of the stem, only solitary fibres curving upwards or downwards, to run further beneath the rind. In the roots of many other arborescent Monocotyledons he constantly saw the vascular bundles, if the root were still young, spread out like a star over the woody layer of the stem; in older roots, on the contrary, they penetrated deeper into the stem, where they then ramified, and lost themselves. Meneghini derives these differences from the different conditions of the course of the sap; the main root (tap-root) and the lowest roots of the stem are formed at the same time, and with the help of the same currents of nutrient sap, as the vascular bundles of the stem, the latter, therefore, pass directly into the fibres of the former; but when roots are formed on the older parts of the stem, the currents of sap cause a stellate expansion of their vascular bundles on the surface of the woody mass of the stem.

Unger has given some contributions to the knowledge of the Monocotyledonous stem, having, in his researches on the Dicotyledonous stem (Ueber den Bau und das Wachsthum des Dicotyledonenstammes, 1840, p. 35), taken a comparative glance at the structure of the Monocotyledons, and, more particularly, subjected the stem of the *Aloineæ* (*Dracæna, Aletris, Yucca, Agave*) to a more minute investigation. With regard to the course and anatomical peculiarities of the vascular bundles, Unger agrees in general with the description I have given, and thus nothing need be said on this point. But from his investigation of the course of development of the vascular bundles, he has been led to propound a definite opinion as to the import of their proper vessels, while I had let this point remain untouched. He traced the development of the vascular bundles principally in the *Aloineæ*, and states that their rudiments are uniformly cellular, that the other systems (the wood and liber portions) make their appearance subsequently at the inner and outer

sides, and that their intermediate portion is to be regarded as their most essential part, since it is not merely that first originating, but also, in all stages of metamorphosis of the vascular bundle, persists under the same form of elongated cells, resembling milk-vessels.

In reference to the blending of the vascular bundles with each other, Unger distinguishes the proper blending (*coalitus*), which consists in the actual fusion into one vascular bundle, from the mere apposition (*symphysis*), in which the vascular bundles are attached together by a dense parenchyma. According to Unger, true blending does not occur in the *Aloineæ* (with the exception of *Yucca gloriosa* and *Agave Americana*), while in other families, especially in the Scitamineæ and Bromeliaceæ, it is frequent.

Of the systems of vascular bundles of the buds and roots of the Grasses, it is stated, that they are special to these organs, and do not pass into them from the stem; this is particularly evident in the roots, but in the vascular bundles of the buds also, a mere anastomosis with the vascular bundles of the stem occurs, and only individual ones become mingled with those of the stem.

With regard to the period at which the vascular bundles running to a leaf originate, Unger found that the slender fibres occurring in the Palms and Grasses, which do not enter into the interior of the stem (at least, certainly not in the Grasses), are of later origin than the stronger vascular bundles which run from the inner layers of the stem into the leaves.

Lestiboudois expresses an opinion very different from that of his predecessors, in reference to the mutual blending of the vascular bundles, in his very valuable treatise on the Structure of the Stems of Plants (Études sur l'Anatomie et la Physiologie des Végétaux, 1840), in which he has wholly relinquished his earlier views of the structure of the Monocotyledonous stem.

The Palm-stems examined by Lestiboudois belonged to species, the systematic names of which are unknown

to him; they were chiefly two stems, imported for commercial purposes, one of which has black, the other red fibres. Lestiboudois believes the slender fibres of the outer layers to originate partly from the cellular rind, and partly in the form of branches of the larger fibres; and he states that, in consequence of manifold ramifications and lateral connexions, they form a continuous network. In the upper end of the fibres, entering the leaf, he likewise finds not only, frequently, a division of them into several branches, entering separately into the leaf, but also when they enter undivided into the leaf, dense ramifications which become blended with other fibres. He further assumes that the fibres are not all formed at the periphery of the stem, but that from the central vascular bundles, and from those running in the hard, woody layers, slender fibres, like those lying beneath the rind, run out; and from this he draws the conclusion that it is clear that all fibres are destined to produce new fibres. The particular fibres do not, indeed, run in unbroken continuity through the whole stem, but the fibres of the different parts of the stem are so connected that they spring out from one another, and before they emerge into the leaf, give off branches, which are destined to replace, in the upper part of the stem, the fibres emerging into the leaves lower down. From this it is clear, that in the Monocotyledons the life is not exclusively seated in the outer layers; if the stem be cut into all round, down to the hard layer, in a *Yucca* or *Aloë fruticosa*, the plants will live, unhurt, for many years; the only phenomenon which appears in the wound, being the formation of a protruding collar on the upper border of the incision, from out of which numerous roots frequently break forth.

Before I follow the author further in his exposition, I have to state, that I am very far from implying a doubt of the correctness of his observations, but yet I cannot forbear from questioning the universality and frequency of these ramifications in the vascular bundles of the Palms. I have stated above, that in particular stems of the *Cocos-*

like division, for instance, in *Lepicodaryum gracile*, I had found many slender evascular fibres among the perfect vascular bundles, in the interior of the stem; in the stems which I examined I could not trace the origin of these fibres, and therefore cannot say whether they were formed by ramification of the vascular bundles, as in Lestiboudois' stems; in any case, however, the occurrence of these fibres is quite unusual, and to be regarded as an anomaly in the stems of Palms, and I found none of them in the Palm-stems which are met with in the shops with us, and which, doubtless, belong to the same species as those which Lestiboudois calls "the Palms with black fibres." That the vascular bundles do not all end below in a slender fibre lying beneath the rind, but that it does happen a fibre becomes blended with another at its lower extremity—i. e. in tracing the fibre from below upwards, it appears like a branch of another fibre—I have likewise mentioned; but this condition occurs only in very few fibres. As to the condition of the multitude of thin, lower fibres lying beneath the rind, whether they are lost in the cellular tissue or blended with other fibres, I am unable to say, for the solidity of the tissue in this situation rendered it impossible for me to make out this point accurately. An anastomosis of these ends of the fibres into a connected reticulation (as in *Yucca*, *Xanthorrhœa*), decidedly, I believe, does not occur; only with the existence of such would such a universal connexion of the fibres with each other occur, as Lestiboudois claims for the Palms. I cannot find in the Palms a connexion and ramification of the upper parts of the fibres, like that described by Lestiboudois, I therefore think that their assumption by Lestiboudois is rather deduced from the analogy of the Palm-stems with those of *Yucca* and *Aloë*, than founded on actual extensive researches on the former. Lestiboudois found this ramification of the fibres in a high degree in *Yucca*, *Aloë fruticosa*, and especially in *Pandanus*. When he deduced from these observations the conclusion that the fibres of the Monocotyledons are

formed in a different way from those of the Dicotyledons, originating from ramification of the old vascular bundles, while in the Dicotyledons the new fibres are deposited between the bark and the ends of the older fibres which emerge into the leaves, this conclusion is not justified by the anatomical character of the Dicotyledonous stem, since it leaves wholly out of sight the fact, that in very many Dicotyledons the lower end of some of these vascular bundles stands at least in quite as close organic connexion with other vascular bundles as in the Monocotyledons; so that the younger vascular bundles have much resemblance to those of the Fern-stem in respect to the arrangement and union.

Lestiboudois devoted especial attention to the roots of the Monocotyledons; from the examination of them he drew two conclusions: 1. Their vascular bundles are not formed by gradual elongation of those of the stem. 2. Their growth is endogenous, for their vascular bundles are perfected from without inward, and new vascular bundles originate in the interior of the root.

Schleiden (Wiegmann's Archiv, 1839, p. 220; Grundzüge der wiss. Bot. i, p. 220) directs attention to the point that the vascular bundles are developed in a similar manner in the Monocotyledons and the Dicotyledons, the part turned towards the interior being that which first originates, and he considered it to be the only thorough distinction between Monocotyledons and Dicotyledons, that in the latter the formation of new elementary organs proceeds indefinitely in the cambium-layer of the vascular bundle (whence he calls these vascular bundles *unlimited*), while in the former this development ceases at a certain epoch (*limited* vascular bundles), and the elementary organs of the cambium-layer assume the peculiar form in which I have described them under the name of proper vessels. With regard to this distinction, the knowledge of the facts on which it depends is not new, only the explanation, in so far that Schleiden quite correctly explains the continuous deposition of new layers of wood in the

vascular bundle of the Dicotyledons as a growth belonging to the vascular bundle itself, while I had derived it from the interposition of the lower ends of younger vascular bundles, running to leaves situated higher up, between the liber and wood of the old bundles; a theory against which Unger, also, has declared himself with convincing reasons (Ueber den Bau und das Wachsthum des Dicotylenstammes). Perhaps it may not be superfluous to remark, that this distinction only refers to part of the vascular bundles of the Dicotyledons, since the part entering the leaf and traversing it is likewise limited in its increase of thickness.

I now turn to Mirbel's excellent essay on the Structure of the Date-palm (Comptes rendus de l'Académie des Sciences, 12 June, 1843). In 1839 the author went to Algiers, in order to have an opportunity of examining a full-grown Date-palm in a fresh condition; and as the result of four years' labour, directed especially to the investigation of the terminal bud of this Palm, he laid before the Paris Academy a theory of the structure and growth of the Monocotyledons, which is opposed to my statement in several points.

With reference to the connexion of the roots with the stem, Mirbel agrees on the whole with my views, but assumes a more intimate connexion of the vascular bundles of the roots with those of the stems, than I met with in my researches. According to his statement, the fibres which come from the middle and neighbouring parts of the root, penetrate into the interior of the stem, between the vascular bundles of the latter, and lose themselves among them, in such a way that their extremities cannot be accurately made out, while fibres derived from the circumference of the expansion formed by the root in the stem, are distributed upwards and downwards, in the superficial layers. In reference to the latter, Mirbel thinks that they probably furnish contributions to the suckers which break forth abundantly from the base of the stem in the Date-palm and *Chamærops;* of the former, Mirbel

thinks they may stand in connexion with the leaves. When Mirbel then proceeds, that my statements as to the relations of the vascular bundles of the roots to those of the stems are not contradicted by this, but only carried out to their real extent, I am far from calling in question the accuracy of the observations made by Mirbel on the Date-palm, but must defend myself from the construction which must almost necessarily be attached to Mirbel's expression, that, namely, my observations, and the conclusions to be drawn from them, had been essentially modified, and that a more direct transition of one part of the vascular bundle of the root into that of the stem occurs universally. The essential point which I established by my observations on the roots of Monocotyledons, is the fact that the root is an independent structure, possessing its own special system of vascular bundles, that these are not gradually elongated outwards, towards the point of the root, but also increase in length in the posterior extremity, lying in the stem, penetrate into the stem from the cellular mass which constitutes the basis of the root-bud,—form an interlacement with the vascular bundles of the stem, and become attached to them.

All doubt as to this independence is removed by the investigation of the root-bud, for its vascular bundles are originally entirely separate from those of the stem ; but it is also perceptible, subsequently, that at least the greater proportion of them are not directly continuous with the vascular bundles of the stem, but, with an alteration of their structure, an interlacement is formed, in which they apply themselves to the sides of the vascular bundles of the stem, without actually passing over into them. The bundles of the branches of the root stand in the same relation to those of the root as the latter do to those of the stem. On account of the smaller number of vascular bundles of the root-branch and the root, and the very different diameter of the vessels of these two organs, it may be observed, with the greatest certainty, that an immediate transition of either set of vascular bundles into the other

does not exist. This investigation is far more difficult at the place of union of the root with the stem; but in a few Palms, particularly in a *Cocos* stem, in which the cellular tissue had been destroyed by rotting, I examined, at the point of entrance of several roots, the interlacement which their vascular bundles formed with those of the stem, and traced separately all the vascular bundles which ran through these, without finding a transition of a root-bundle into a stem-bundle; I therefore think that I may safely deny the occurrence of such a transition, at least in these cases. At the same time I do not wish to question, that in other cases part of the vascular bundles entering the stem from the root become mingled with the bundles of the former, and run on with them, as I have myself stated this to be the case with the fibrous bundles, which, in some Palms, lie with their lower extremities in the rind of the root, and as Meneghini found in the isolated fibres of the woody portion of the roots of *Chamærops*; but I believe I may deny that this condition occurs always and necessarily, and that a conclusion adverse to the independence of the vascular-bundle system of the Monocotyledons is to be deduced from it.

In regard to the structure of the stem, Mirbel directed his attention chiefly to the settlement of the question, whether the vascular bundles grow downwards from the leaves into the stem, or are developed in the contrary manner. He is in doubt whether, in my description of the Palm-stem, where I have described the course of the fibres downwards from the leaf, I merely intended to denote the mechanical conditions of their position, or the direction in which they are formed. I scarcely think that I could have expressed myself more distinctly on this point, that I meant only the former. I was unwilling to propound any definite opinion on the second question, because, in the absence of sufficient material, I was unable to solve it with certainty.

Mirbel first investigates the question, whether the vascular bundles run down from the leaves to the base of the

stem, and founds his answer on the following considerations. His Date-palm was 18·60 meters high, the base, clothed with roots, 34 centimeters in diameter; above the root-bearing part the surface of the stem had suffered from the influence of the atmosphere, and its diameter here amounted to 25 centimeters; the upper part was covered with leaf-scars, and almost cylindrical. Mirbel then concludes, that if the fibres originated in the leaves, and all reached down to the base of the stem, or, on the other hand, if all the fibres originated at the base of the stem, and ascended up into the leaves, the stem must necessarily have a conical form, on account of the accumulation of the fibres at its lower end. In like manner is opposed to either of these views a circumstance, which was undoubtedly known to me, namely, the spindle-shaped expansion of many Palm-stems in the middle, which I could not explain according to my theory, but which affords nothing remarkable now he has found that the fibres originate at all heights in the stem. The most certain evidence, however, against the opinion that the fibres run from the leaves to the base of the stem, is furnished by the following exact measurements. In the Date-stem he examined there were 337 leaf-scars on a length of one meter, the entire stem had, therefore, borne about 6268 leaves. At the base of one petiole Mirbel found 500 fibres 1 millimeter thick, and 400 fibres $\frac{1}{9}$th of a millimeter, which he estimated equal to 44 of the larger fibres; for the vagina of the leaf he reckoned 100; therefore, altogether, 644 for a leaf, and for all the leaves of the stem added together, 4,036,592 fibres. Besides these, account must also be taken of the fibres which run to the spathes and flower-stalks, and, moreover, the enormous number of capillary fibres which occupy a considerable space in the hard and firm crust of the oldest portions of the stem. Leaving these last out of sight, the fibres running to the leaves furnish a sufficient proof against my theory, since, if these fibres ran down to the base of the stem, the cone formed by them at the bottom would

be 2·01 meters in diameter, and 6·33 meters in circumference, while, in reality, the said stem was only 25 centimeters in diameter above the root-stalk.

Before I follow Mirbel's researches further, I must subjoin a few words to the foregoing. In the explanation of the structure of the Palm-stem I have called attention to two circumstances, to the course of the fibres, and to the alteration of their structure and size in different parts of their course. To the latter point, Mirbel, in advancing the preceding calculation in opposition to my view, paid no attention, but it was necessarily required that he should have done so, to afford any useful result. Mirbel says the Palm-stem swollen in the middle is a complete contradiction to my theory. The fact that such stems occur was well known to me, but by itself it was not of sufficient importance to give rise to a different theory. That with the development of the stem and the increase of the force of its vegetation, the upper leaves are larger than the lower, and a greater number of fibres run from them into the stem, than from the lower; that the stem must consequently acquire greater diameter at the base of these leaves than at the base of the lower leaves—all this is exceedingly simple. This increased thickness must be continued to the lower part of the stem, and the latter thus acquire a conical shape if the vascular bundles run down without change of thickness to the base of the stem, but by no means if, at the place where they appear beneath the surface of the stem, they become so slender, that in spite of their accumulation they still form no equivalent for the greater size of their upper ends, situated higher up in the stem. The plates of my 'Anatomy of the Palms' afford evidence of how considerable this attenuation is; they are drawn with the Sömmering's reflector, the relative sizes of the various parts of the same figure are therefore accurate, and a comparison of the vascular bundles with the thin fibres lying beneath the rind, shows that the transverse section of the latter is frequently a hundred times smaller than

that of the former. With this considerable attenuation of the vascular bundles at their lower extremities, with the more distant position of the upper parts of them in the interior of the stem, and with the crowded position of their lower filiform extremities, even if the fibres did run down in the stem, the lower part of this would only undergo a relatively slight increase of thickness, and a spindle-shaped thickening in the middle would still always be possible. Mirbel, on the other hand, reckons as if all the vascular bundles arrived at the base of the stem of the same thickness as they are when they emerge from the leaf, and comes to the conclusion, that in his stem the mass of these fibres would form a cylinder, which in the transverse section would display a surface nearly sixty-four times larger than the cross section of the stem actually was. To make a calculation of any use, it is necessary to settle the thickness of the lower end of the fibres. I have before me the discoid slice of a full-grown stem of *Phœnix*, 34 centimeters in diameter, in which the fibres lying beneath the rind average 0·127, therefore nearly $\frac{1}{8}$ of a millimeter in diameter. Consequently, if we assume with Mirbel that the upper and middle portions of the fibres are 1 millimeter in diameter, the cross section of about 64 of these fibres would equal it. If, then, all the vascular bundles reached the lower end of the stem under the form of such slender fibres, taking the number of vascular bundles of Mirbel's stem, the sum which he obtained must be diminished sixty-four times, i. e. the mass of these fibres would form a cylinder of the thickness of the Palm-stem Mirbel examined. I do not at all intend to attach any weight to this calculation, its incorrectness is too evident, since, according to it, the stem would consist of a compact fibrous mass; but it shows that a calculation, if not based on much safer grounds than Mirbel's rests on, cannot lead to any useful conclusions.

I admit unconditionally that my statement, that the vascular bundles run down, in the form of fibres, to the

base of the stem, is incorrect as regards the Palms. I was led to the assumption by the investigation of too young specimens (for I only had such in an entire condition, and the portions of full-grown Palm-stems at my disposal were merely short pieces), as well as by too wide an extension of the analogy with the stems of *Dracæna*, *Yucca*, &c. The grounds on which I now hold the view that the fibres run down to the base of the full-grown stem is false, are anatomical. It is clear, that in the transverse section of an old Palm-stem, we ought to find beneath the rind the fibres which are only just beginning to be formed, as Moldenhawer states that he did, although he had indeed no large stems to investigate; now in the examination of sections of old stems I have not seen this, but all the fibres lying beneath the rind were composed of thick-walled cells, consequently were old. A subsequent growth of the fibres beneath the rind of full-grown stems, therefore, does not take place. The matter is altogether different in respect to the stems of *Aletris*, *Dracæna*, &c.; here there is a layer beneath the rind perfectly comparable with the cambium-layer of the Dicotyledons, in which parenchymatous cells and fibrous bundles grow subsequently, which formation of new structures gives rise to continual increase of thickness of these stems. It is proved by this that the fibres terminate higher up in the stem in the Palms, and that in them must exist a condition similar to that in many Dicotyledons, where the vascular bundle can only be traced down through a certain number of internodes.

Passing now to the most important part of Mirbel's treatise, the examination of the terminal bud, he states that he found two slits, one above the other, in the centre of the flattened, concave, excavated apex of the stem, composed of nascent cellular tissue (to which he applies the name of *phyllophore*), these slits dividing the cellular tissue into superimposed layers. Of these layers each, according to his views, represents a nascent leaf; the upper one is elevated into a vesicle, and this becomes

torn away, in a circular direction in the greatest part of its circumference. The isthmus is developed into the petiole, the upper part of the vesicle becomes erected, acquires the shape of a spoon, and is converted into the leaf, the vagina of the leaf appears to grow out from the wound which the torn leaf leaves upon the phyllophore. The leaf acquires the form of a hood, its border having an irregular thickening; the two lateral halves of the hood are formed of the two series of leaflets, and the thickened edge, which unites the points of the leaflets, subsequently becomes absorbed.

The description of this process does not agree in the least with what I observed in regard to the earliest period of the formation of the Palm leaf. I examined, in reference to these statements of Mirbel, the terminal buds of *Phœnix* and *Cocos flexuosa*, but found, as in other Monocotyledons, such as *Agave*, *Yucca*, no trace of origin of the leaf under the form of a circularly torn vesicle as described by Mirbel, but saw the leaves shoot forth from the axis in the form of obtuse papillæ. This papilla is at first narrow, in proportion to the portion of the axis on which it stands, since the first-formed part of it corresponds to the apex of the future leaf; the further it is developed, the more the base rises from the surface of the stem, so that in the Palms an indication of the vagina of the leaf is visible at a very early period. I cannot understand how Mirbel came to the idea that the leaf originates in the form of a vesicle, and that several such vesicles lie one above another; he must have been led to this view by a longitudinal section which did not pass exactly through the axis of the bud, and thus have met with sheaths of young leaflets (which in the inner parts of the bud are not cylindrical, but have the lower part spread out almost flat), and have taken them for the rudiments of the whole leaves. I deduce another reason against the assumption that the leaflets originate from closed vesicles, from the observation of a monstrous formation which I found in a branch of *Phœnix*, the axis of which had grown out to the length

of some two inches. About six leaves on this had no amplexicaul vaginas, but the lower sheath-like portion of all the leaves formed a connected lamella, passing round the stem in a spiral line, from the upper part of which normally-formed leaves were given off at intervals. The upper leaves had perfectly closed sheaths. Similar confluence of several leaves into a continuous leaf-spiral have, as is well known, been repeatedly observed in plants with verticillate leaves, ex. gr. in *Casuarina*, whether they have elsewhere occurred in amplexicaul leaves I know not; in any case, the case just described appears to me inconsistent with the idea of the origin of the leaves in the form of closed vesicles.

The development of the originally simple leaf into a pinnate leaf is very peculiar in the Palms. Since Mirbel rather indicates than describes this process, a more minute explanation of it will, though not very closely connected with the object of this essay, perhaps be acceptable to many readers. De Candolle, in his 'Organography' (i, 304), has already observed, that the division of the Palm-leaf into pinnæ, or into lobes of a fan-shaped leaf, takes place in a manner altogether peculiar, namely, by a tearing up of the structure. De Candolle looked at this process much too roughly; he evidently made his observations on a leaf already developed to a considerable degree; I was therefore quite justified in rejecting this notion of a mechanical description in my 'Anatomy of the Palms,' but in like manner did not go far enough back in the investigation of the young leaf, in its earliest stages of development, to enable me to give a satisfactory explanation of the process. I had indeed correctly made out that the separation of the pinnæ is completed long before the unfolding of the leaf, and that they are not connected together in the bud by leaf-tissue, but by a loose parenchyma, which is blended in a very narrow line with the border of the leaf, is connected with the pubescence of the leaf, and dries up and falls off with it, whereby the leaflets are allowed to separate from each

other and become free; when, on the other hand, I explained this tissue as a peculiar form of the pubescence, I was wrong, as the following observations will show. I traced the development of the leaf in *Phœnix* (pl. I, figs. 9-13) and *Cocos flexuosa* (figs. 1-8); in both, the young leaflets (figs. 1, 12, 13), until they attain the length of about five millimeters, are composed of a connected tissue, which in the middle, as rudiment of the future petiole, is thicker, and runs out into a relatively thin border at each side. At a later period a smooth furrow is formed between the thickened mid-rib and the margin of the leaf (fig. 2), at the bottom of which are subsequently met with, nearly approached, somewhat excavated cross-striæ (figs. 3, 4), the tissue of the leaf, however, being still continuous. These cross-striæ are afterwards converted into narrow slits (figs. 5-11), which in *Cocos flexuosa* penetrate the entire thickness of the leaf, so that they are visible on the upper and lower surfaces (fig. 7 *b*). The further development shows that the part lying between each pair of slits becomes perfected into a leaflet, and in a cross section (fig. 7 *c*), or, still better, in a longitudinal section, it is perceived that these pinnæ are folded together, and that the mid-rib, at which the fold takes place, is in *Cocos* on the upper surface, so that consequently twice as many slits are visible at the under side of the leaf as at the upper (fig. 7 *c*). The margin of the leaf, at which the points of all the pinnæ are blended, forms a continuous cellular mass, which ends externally (fig. 8*) in an acute angle (the border of the previously undivided leaf). With the advance of the development of the leaf this cellular mass dries up, and is thrown off in the form of a brown filament, by which the leaflets are set free. In *Phœnix* (figs. 9-13) the matter is rather different, as the mid-rib of the leaflets is turned toward the under side of the leaf, and the cellular mass which connects the pinnæ is not merely blended with their summits, but is continued over the whole of the upper surface of the leaf as a rather thick membrane,

and is blended with the upturned margins of the pinnæ, whence the slits between the latter are only visible at the under side of the leaf. The leaf, therefore, originates as a continuous mass, and the pinnæ owe their origin to an actual division of the leaf: the division, however, does not advance from the margin of the leaf toward the mid-rib, but relates only to the surface, not affecting the border, nor, in *Phœnix*, the upper layer of the tissue of the leaf. This permanently undivided mass of cells is distinguished from a true pubescence, to which it bears much resemblance, by its origin, since it is not a growth from the surface of the organ, but forms an actual part of the tissue of the leaf, as well as by the circumstance that in some of the Palms, for example in *Phœnix* (but not in *Cocos*), vascular bundles run into it.

Return we from this digression, to Mirbel's description of the bud. He states that there run through the tissue of the bud a countless number of transparent, very delicate fibres, which converge from the whole internal periphery of the stem toward the central portion of the phyllophore, where their upper extremities approach the young leaflets, sooner or later to enter into direct connexion with them. In a few instances he has hit upon these fibres at the moment when they were running into the weakly-indicated rudiments of the leaves. Those physiologists who believe that the fibres run down from the leaves had certainly never an opportunity of seeing the terminal bud of a vigorous Date-palm, or they would have left nothing for him to do. A glance is sufficient to convince that the upper ends of these fibres are very young compared with the lower, that they consequently grow from below upwards. If they sprang from the leaves, they must be old and hardened at their point of origin, long before they reached the base of the stem.

This proposition contains the nucleus of Mirbel's doctrine of the structure of the Monocotyledons. The remark that earlier labourers at the anatomy of Palms had no terminal bud of a vigorous stem to examine, is unfortu-

nately, in my own case, only too well founded, and if I venture, notwithstanding that I have not the appliances of the Paris Academician, to subject his researches to a criticism, I know well the difficulty of my undertaking, yet I hope that the reasons which I have to adduce will not be without weight. That the first glance at the section of a Palm-bud will not force the conviction upon every one, that the fibres grow from below upwards, is proved most decisively by Gardner saying, that the greatest sceptic would only need to see a longitudinal section of a Palm-stem bearing its leaves, to be convinced that its woody substance is formed from the leaves (Annals of Nat. History, vi, 61.) I unfortunately had no larger buds at my disposal than the terminal buds of a stem of *Cocos flexuosa* about two inches thick, and of young stems of *Phœnix*. From an examination of these buds, made in reference to Mirbel's views, I have nothing to object to the correctness of his anatomical statement, that in *Phœnix* the vascular bundles running to the young leaves of the bud, are harder and more developed below the phyllophore than in it, where they are in a soft, gelatinous condition. But does the conclusion deduced from this fact by Mirbel, that the lower parts of the bundles are older than the upper, necessarily follow from it? At first sight, undoubtedly, since it is a general fact that young woody bundles are soft, old ones hard. But it is a totally different question, whether the hardness of them is connected simply with their age, or at the same time and in a higher degree with the stage of development of the part in which the vascular bundles lie. Mirbel assumes the former; I believe the latter may be proved. Calling to mind that in the articulated plants with elongated internodes, as in the Grasses, Pinks, in *Ephedra*, a yet imperfectly-developed internode is already completely hardened above, where it is exposed to the air, while below, so far as it is inclosed by the sheath of the lower leaf or verticil of leaves, its internode is still of an herbaceous softness, we have here a case which stands in the most glaring contradic-

tion to the fundamental proposition on which Mirbel rests. Mirbel says, because in the Palms the vascular bundles are softer above than below, their lower portion is older, they consequently grow from below upwards; with equal right he would assume the reverse if he split an internode of *Zea Mays*. Moreover, if we remove the leaves from a terminal bud of *Phœnix*, we find in its half-developed leaves, which have attained a length of about 1 to 3 lines, the part of the petiole projecting from the bud already green and firmly lignified, while the base of the petiole and sheath are uncoloured and very soft; the vascular bundles of the upper part are found completely lignified, those of the lower portion still half gelatinous and translucent, in short, we find here between the upper and lower ends of the vascular bundles (only in reversed order) the same differences as in the vascular bundles of the stem. Shall we conclude from this that the vascular bundles of the leaves grow from above downwards, that the upper part of them is so much older than the lower? This no one will wish to assert, since in the Palm-leaf, it must be concluded, from the fact that leaflets still very small have a sheath, that the growth of the leaf depends on an expansion of the very young leaf in all directions, and not on a subsequent after-growth of its lower portion. From these circumstances, it certainly follows that the greatest differences of solidity and completion of structure occur simultaneously in different parts of the same vascular bundle, and may be caused by the transition from the rudimentary to the lignified condition proceeding with different rapidity in different parts of it, and going on parallel with the unequal growth of the organs in which the vascular bundle lies, since, in general, the upper part of the leaf attains its full development first, and, in the slowly-growing Palm-leaf, a long time before the lower portion; the same holds good in the vascular bundles of its petiole, and the direction in which their lignification proceeds, can by no means be regarded as an index of the direction in which their rudiments made their appear-

ance in their original formation. A vascular bundle which runs from the summit of the petiole of such a half-developed leaf, through the petiole and bud, to the outer surface of a part of the stem situated far lower down, may, according to what has just been said, exhibit its complete development and solidity at both ends, which lie in organs already completed and solidified, while its middle portion, in its course through the lower part of the petiple and through the upper soft portion of the stem (the phyllophore) concealed in the bud, is gelatinously soft, and, in reference to the anatomical completion of its individual elementary organs, still in a young condition. In the same proportion as these soft parts advance in development, as the part of the phyllophore through which the vascular bundle runs becomes part of the stem, and the petiole and leaf-sheath attain their full size and become solidified, will the soft part of the vascular bundle also increase in size and internal completeness, till its growth is finally terminated, and it is solidified. This, and nothing further, do we learn from a view of the section of a bud, and when Mirbel finds in the increase of solidity which the vascular bundles exhibit from above downwards, a proof of the direction in which they originate, the validity of this conclusion must be altogether contested.

The question, in which direction the vascular bundles are formed at their first origin, can only be decided by direct observation of the process of their origination; therefore, only by microscopic investigation. Mirbel did not neglect researches of this kind, and he states, that he sometimes caught the vascular bundles at the moment when they were betaking themselves into the rudimentary indications of the leaves. In the examination of the terminal buds of various Monocotyledons, especially in *Iris*, *Acorus Calamus*, of the bulbs of *Narcissus poeticus*, I came to the result, that the first indications of the vascular bundles, in the form of transparent streaks, are to be met with beneath the youngest leaves, in the axial portion

of the bud, before they appear in the leaves, and that, subsequently, the origin of the vessels in these rudimentary vascular bundles follows in the same direction. This result has been fully confirmed by the researches of Schleiden (Grundzüge, ii, 189), Meneghini (Intorno alla struttura del tronco delle Monocotiledoni, in Miscellanee di Chimica, Fisica e Storia naturale, 1843), and Naudin (Ann. des Sc. nat., 1844, i, 162); and after these accordant observations, there can be no doubt that the upper end of the vascular bundle grows from below upward, and that we have to seek its origin in the stem, and not in the leaf. But it is quite a different question, whether this process of development occurs throughout the whole of the vascular bundle, or if its lower end, running downward in the stem, grows in the opposite direction. Mirbel assumes the former, and assures us that in the Palms, the same vascular bundle has already, at its lower end springing from the interior of the periphery of the stem, the characters of developed wood, and exhibits in its intermediate parts, the half-solidified condition of the alburnum, while at its upper extremity it consists of nascent tissue. Has Mirbel really observed this? I here take the liberty to doubt. According to my own observations, the vascular bundle of a Palm, the lower end of which already exhibits a ligneous solidity, goes, not to the rudiment of a leaf, but to one already tolerably advanced in development; therefore, if the portion of it lying in the upper part of the stem be still very soft, from the causes explained above, this can give no further result as to the mode of its first production. We can only arrive safely at such by tracing downwards one of these vascular bundles, the upper part of which has not yet reached a leaf, and observing its further gradual development. From the great number and the entangled condition of the vascular bundles, I was unable to do this in a Palm-stem, and my efforts to make out this point by direct observation totally failed. When, in spite of this, I venture to discuss the question, and to deduce a decision

of it from more distant phenomena, I am fully aware that this proceeding can claim no certainty, but at most a certain degree of probability; I nevertheless hope that such a mode of considering it will not be altogether useless. In the first place it has to be inquired, whether a developing vascular bundle always grows in one direction, or whether cases do not occur where its two ends become elongated in opposite directions. In my opinion, the latter case undoubtedly occurs, especially at the point of insertion of a root upon a Monocotyledonous stem, and of a branch of one of these roots upon the main trunk. In both these cases, and especially distinctly in the latter, we see vascular bundles originate in the cellular node in which the formation of the root begins, the end of which toward the point of the root, increases in length with the further growth of the root, while the other end penetrates, in the opposite direction, into the stem or primary root. In an analogous manner, as is again to be observed more clearly in the Monocotyledons than in the Dicotyledons, the bud which is developing into a leafy branch, also possesses its proper system of vascular bundles, independent of that of the stem, the lower extremities of which pass into the stem, and spread themselves out over a lesser or greater portion of its ligneous mass. Now, these vascular bundles are nothing else than the inferior extremities of the vascular bundles of this branch, and the most ready supposition, on seeing these fibres passing over into the stem, is that they have been developed from above downwards. To this explanation, which immediately presents itself, it may certainly be objected, that the fact of the passage of that vascular bundle into the stem, does suffice to prove that this is perfected in the direction from above downward, for the formation of that vascular bundle in the stem itself may be caused by the presence of the branch, through the attraction it exerts on the sap-bearing substance of the stem, and it may grow from the stem upward into the branch. But the direction which the fibres lying beneath the rind of Monocotyledonous stems

assume when the stem is wounded, appears to afford an evidence that their formation actually does take place from above downward. I have before me the stem of a *Yucca*, in which many branches were sawn off from the surface during the life of the plant, and which had otherwise undergone injuries penetrating as far as the fibrous layer. On these wounded places over-growths have been formed, as in a Dicotyledonous stem, in which the fibres run down from above to the injured part, till they reach the upper border of the wound, then deviate to each side, run down along the lateral borders, and at some distance below the injured spot again approach together from each side, in a very acute angle. In this way an over-growth is formed above and at the sides of the wound, but is absent at the lower border. If the fibres grew upward from below, as Mirbel assumed, they should reach the lower margin of the wound, deviate to the side of it, and gradually approach together again above it; the over-growth ought, therefore, to originate at the lower and not the upper side of the wound. It is to be observed here, that this over-growth is not effected by an increasing thickening of old vascular bundles, existing at the time of the injury, as in the Dicotyledons, but is formed by newly-developed bundles, which are entirely separate from those subjacent (as in general, also, in the normal growth of the stem, the superimposed fibrous layers are not to be compared with the annual rings of the Dicotyledons, but to be regarded as entirely isolated structures), which is most clearly shown in the direction of the spiral lines in which the fibres run, since these spirals alternate to the right and left, in the successive layers, in a manner analogous to what is found in *Xanthorrhœa*.

The analogy between the structure of the stem of a *Yucca* and a Palm is so great, that we are justified in drawing a conclusion from the phenomena we observe in the former, as to the processes occurring in the latter. The distinction between the two stems lies chiefly in this, that in *Yucca* the lower extremities of the vascular

bundles run down to the base of the stem in the form of a close fibrous network, and that in consequence of the continued deposition of new fibrous layers, the stem exhibits an uninterrupted growth in thickness, while in the Palms the lower fibrous extremities of the vascular bundles, as a general rule, remain simple, and do not run downwards to the base of the stem. The case observed by me in *Cocos*, of the solution of the vascular bundles into a number of slender fibres (p. 9) is to be regarded as an approximation, in the Palms, to the structure of this fibrous reticulation. These differences occurring between the stem of *Yucca* and that of the Palms are undoubtedly not of sufficient importance to allow of our supposing an essential difference to exist in the mode of development of the vascular bundles. Since, then, in every Monocotyledonous stem vascular bundles appear, in consequence of the development of a branch, which, without the formation of that branch, would not have originated,—since these vascular bundles form a greater mass, and spread so much more widely over the stem from the base of the branch, the older this latter becomes,—since in *Yucca* the course of the vascular bundles exhibits such mechanical conditions in the vicinity of a wound on the stem, as must result from a downward growth of the vascular bundles on the stem, it is quite justifiable for me to declare that Mirbel's view, that the vascular bundles of the Palms grow from below upwards, is an opinion opposed to the phenomena of the growth of the Monocotyledons; and to presume, on the contrary, that the lower portion of these bundles is developed in the direction from above downwards.

Meneghini came to the same result through a series of deductions altogether different from mine. He had already stated, in his first paper on the structure of Monocotyledons (Richerche sulla Struttura del Caule nelle Piante Monocotiledoni, 1836, p. 77), that the formation of vascular bundles was caused by definite currents of nutrient sap, without, however, carrying out this view more minutely.

In a more recent treatise (Intorno alla struttura del tronco delle Monocotiledoni), he sets up the following theory, as to the connexion between the currents of sap and the origin of the vascular bundles, and as to the dependence of the direction in which the fibres are developed on the course of the sap. The nascent leaf in the centre of the bud forms the focus of the sap-currents, which converge from the periphery of the bud to the leaf, and give rise to the production of vascular bundles. The portion of the vascular bundle which has originated in this way, forms, when the leaf, in the course of its further development, has passed out to the periphery of this stem, the inferior portion of its vascular bundle, since the upper part of it grows after that first portion, gradually, and in proportion as the leaf is developed and assumes its subsequent position. During the perfecting of the leaf, the sap-currents running in toward it, and with them the organization of the vascular bundles in the cambium-layer of the stem, undergo a continually increasing expansion in the direction from above downward. When the leaf has emerged from the bud, and has become green, the superabundant assimilated juices flowing toward it, together with the ascending sap, flow back, and give rise to the formation of liber-cells. The ascending sap, which is so much the less elaborated the nearer it is to the root which absorbs it, must influence the metamorphosis of the cells through which it flows, so much the more powerfully, the nearer it comes to the point by which it is especially attracted; therefore the formation of the vessels, which depends upon it, begins in the leaf and descends from here to the root. The descending sap, on the other hand, which is consumed in the nutrition of the cells, must lose its activity in proportion as it becomes removed from the leaves. The formation of the vessels depends on the ascending, that of the liber-cells upon the descending sap; the first, consequently, predominates in the upper parts of the vascular bundles, the other in their lower portions, and on double grounds

the vascular bundles must, in respect to the organic formation, be regarded as descending from the nascent leaf in the centre of the bud.

Returning to Mirbel's exposition, the manner in which the vascular bundles terminate below in *Phœnix* is not minutely described by him. Neither have I, as already observed, been fortunate enough to make out this point with certainty. It is indeed found, as I stated in my description of the Palm-stem, that a part of the vascular bundles becomes blended with others below, or as phytotomists who ascribe an ascending course to them express it, are branches from other vascular bundles entering into leaves situated lower down; but this condition can only be demonstrated in a very small portion of them, and, in particular, not in the capillary fibres, in which the vascular bundles terminate in the outer layers of the stem. It is probable, therefore, that the majority of the vascular bundles terminate blindly in the cellular tissue beneath the rind. This assumption may appear to create a difficulty in regard to the explanation of the manner in which the sap ascends, but we find exactly the same condition in the vascular bundles of the *corona* of many Dicotyledons—for example, in *Laurus nobilis*, *Quercus*, *Rosa;* where the vascular bundles running into one leaf run down the stem without entering into any connexion with those of another leaf, and become gradually attenuated under the form of thin fibres, which cannot be traced farther down. In these plants, the ascending sap, when it flows through one vascular bundle, must, to reach a second, emerge laterally into the cellular tissue, and from this flow into the neighbouring vascular bundles. The condition, however, as I have already several times remarked, does not occur in all the arborescent Monocotyledons, since in *Dracæna*, *Yucca*, *Xanthorrhœa*, the lower extremities of the vascular bundles grow together at their sides, and in this way form a connected fibrous reticulation over the whole stem.

Mirbel distinguishes different kinds of vascular bundles

in the stem of the Date-palm: 1st, those which occur in the interior of the stem, and form the principal mass of its wood; 2d, capillary fibres, which lie in great numbers in the peripherical region of the stem and the petiole, do not occur in the interior of the stem, and are thirty-six times smaller in diameter than the first. These thinner fibres contain no vessels, but are composed merely of elongated, thick-walled cells. In my description of the Palm-stem, I have likewise directed attention to these differences, and mentioned that the second class of fibres are the inferior extremities of bundles, which, without previously entering into the interior of the stem, run in the outer layers of the stem, and are here mostly converted into true vascular bundles. Unger was the first to remark that these fibres are of later origin than the vascular bundles lying in the interior of the stem; but Meneghini called especial attention to the circumstance, that, as a general rule, the different vascular bundles of the same leaf do not all penetrate to the same depth in the stem, and that this difference depends on the circumstance that the leaf, during its development, passes out from the centre of the axis to the periphery, and each vascular bundle only reaches that point in its internal curve, at which the leaf was actually situated at the moment when the organization of the vascular bundle commenced (Intorno alla Struttura del Tronco delle Monocotiledoni, p. 12).

Mirbel brings a portion of the vascular bundles prominently forward under the name of precursors (précurseurs). He applies this name to them because they are the first which become connected with the leaves. According to him, their number equals that of the leaves in each step of the leaf-spiral (de chaque pas d'hélice), and they appear at intervals, which are measured by the length of the internodes. They lie in a bundle in the centre of the stem; each of them proceeds singly out of this central bundle, and passes obliquely upward into a leaf. On its way, a number of other vascular bundles attach themselves to it. At the point where the precursor leaves the vertical

direction to repair to a leaf, it sends off usually one, more rarely two or three, branches, which ascend vertically upward, and probably run to leaves situated higher up. This is the only example of ramification of a fibre which Mirbel met with in the Date-palm.

The preceding, Mirbel continues, is not at all in contradiction to my statements; but this is not the case with the circumstance that the lower ends of the precursors do not run in a vertical direction down the stem, but repair to the side of the stem opposite to the leaf, whence it results that *all* the precursors which pass to each one of the turns of the leaf-spiral, cross in the central bundle, and form two cones connected at their apices—one erect, the other reversed. Whether the direction in which these fibres diverge from the straight line is the same in all, Mirbel does not express; nor does he make any mention of the fact, that Meneghini devoted especial attention to this point, or of the explanation of it given by that author. From his very laconic treatment of this point, which he speaks of as the most important difference between our works, Mirbel gives me no opportunity of making an accurate acquaintance with and discussing his views; for I must confess that it is not clear to me, from his treatise, how and why he distinguishes the fibres he calls precursors from the other developed vessels,—and that I know nothing of them.

ON THE

NUCLEI, FORMATION, AND GROWTH OF VEGETABLE CELLS.

BY CARL NÄGELI.

PART II.

TRANSLATED FROM

SCHLEIDEN U. NÄGELI'S ZEITSCHRIFT F. WISS. BOTANIK, 1846.

BY ARTHUR HENFREY, F.L.S.

VEGETABLE CELLS.

PART II.

In the First Part of this essay I endeavoured to demonstrate, in the first place, that nuclei occur in all vegetable cells, and that they are utricles; secondly, that in one kind of cell-formation (which is called *parietal* cell-formation), the whole contents of the parent-cell become divided into two or more portions, and that around each of these a perfect membrane is formed by the secretion of gelatinous substance, this membrane being in contact in part with the wall of the parent-cell, in part with that of its fellow secondary-cell. I shall hereafter find an opportunity of defending my theories against some objections which have since been made to them. I have delayed the continuation of the essay, which is principally to treat of free cell-formation, because my observations have never appeared sufficient to afford a quite positive conclusion. Even now, in spite of all my efforts, I have only arrived at probabilities in my results on many points, which, however, I will not any longer keep back, but leave the further development and establishment of the doctrine to a happier time.

IV.—FREE CELL-FORMATION.

a. Without visible nucleus.

In free cell-formation without a visible nucleus, the new cells originate, in the contents of the parent-cells, as minute globular bodies, in which, so soon as they have

acquired sufficient size, we recognise an enveloping membrane and inclosed contents.

In *Chlorococcus*, Grev., and *Hæmatococcus*, Ag., the new cells appear as green (in the former genus) or red (in the latter) globules, in which we only perceive a definite outline. When they leave the parent-cell and become larger, we distinguish a colourless membrane inclosing coloured contents. I have never been able to detect any sign of a nucleus. It appears as if merely small isolated portions of the contents became agglomerated, assumed a perfectly spherical form, and produced a membranous coat. The rest of the contents of the parent-cell are gradually dissolved.

Valonia utricularis, Ag., consists of one large cell. On the inner surface of its membrane lies the mucilaginous layer. The *germ-cells* (*Keimzellen*) originate in this. At first they have the appearance of minute drops of mucilage. The membrane cannot be detected until they have become larger, granular, and green.*

The origin of the germ-cells (spores) in the thecæ of Fungi and Lichens is accompanied by the same phenomena. At first they present themselves, sometimes in the form of homogeneous drops of mucilage, sometimes as little hollow globules, the former in clear, diluted, the latter in dense, mucilaginous, cell-contents of the theca. In both cases the nascent spore-cell originally exhibits only a definite outline, and a distinct membrane only at a subsequent epoch.† No nucleus is visible in these; at a later period, when the cell has increased in size, and the contents have become transformed, a nucleus is seen in some instances.

In *Coleochæte scutata*, Bréb., the germ-cells appear in the parent-cells, at first as little green, homogeneous globules, on which a membrane afterwards becomes visible. A nucleus may sometimes be detected in the fully-de-

* For a more minute account, see Nägeli's New System of Algæ. (Die Neuen Algen-systeme, &c. Zürich, 1847.)

† See Nägeli, Linnæa, 1842, p. 257, Pl. ix, figs. 32, 34, 41, 45.

veloped cell in germination. The examples just given of *free cell-formation, without visible nucleus,* agree with each other in the point that the new cells first appear as little spherical, homogeneous portions of the contents of the parent-cell, around which no membrane, but merely a definite outline, can be perceived. They are, like the contents of the parent-cell, coloured (green or red) or colourless. Not until they acquire greater size, and in most cases, only at the time when they become granular, does the membrane become distinctly visible. A nucleus is never seen in the earlier stages, and appears subsequently only in isolated cases.

I have made a second series of observations on free cell-formation without visible nucleus in Algæ and aquatic Fungi, especially in *Bryopsis, Codium, Anadyomene, Acetabularia, Dasycladus, Conferva glomerata* (*lacustris et marina*), and *Achlya prolifera.* I regard it as an abnormal cell-formation, because it mostly occurs in older cells, and frequently simultaneously with the death of the rest of the cell-contents, or precedes this. If this mode of cell-formation occurs in healthy cells, containing, in addition to colourless, transparent contents, and homogeneous and granular mucilage, which is especially manifest as the mucilaginous layer investing the internal surface of the wall, also chlorophyll-globules and starch-granules, which lie principally in the mucilaginous layer,—at first we see minute, homogeneous, colourless mucilage-globules, the diameter of which is about ·002-·004 of a line. They become larger, finely granular, acquire a greenish colour, and a membrane gradually becomes visible upon them. Subsequently they acquire very various sizes (·010-·060‴), and contents which vary much in quantity, since the chlorophyll sometimes lies upon the wall in smallish quantity, and sometimes gives the cell a deep green aspect by its great abundance.

In the above cases the cells originate and are perfected, without immediately effecting any essential change in the contents of the parent-cell. But if the parent-cells have

begun to decay, the contents (the mucilaginous layer with the chlorophyll- and starch-globules) separate from the wall and lie effused in the cavity of the cell. In this case the new cells do not usually originate as small, colourless, homogeneous globules of mucilage, but as larger globules of the confluent cell-contents, composed of mucilage, chlorophyll, and amylum. On the very outside a layer of homogeneous mucilage is always deposited, and forms a sharply-defined surface. A distinct membrane is quickly produced on this surface. The cell-contents are so arranged within this that the chlorophyll- and amylum-globules lie at the periphery, while the middle part of the cavity is filled with transparent fluid.

These cells, whether they be formed within healthy or decaying cells, originate through *abnormal* cell-formation, and stand, apparently, in no necessary relation to propagation; therefore ordinarily they perish without further development. In isolated cases, however, they behave like germ-cells (spores), and are developed into new plants.

In Plate II, figs. 1 and 2 represent an old utricle of *Bryopsis Balbisiana*, wherein abnormal cell-formation is occurring. In fig. 1, *a* and *b*, the cell-contents are dead and beginning to dissolve. They consist of scattered chlorophyll-globules and mucilage-granules. The parts *c* and *d*, on the contrary, possess active living contents, surrounded by a mucilaginous layer. They are connected together by a mucilaginous cord: this cord is the remnant of the mucilaginous layer which formerly coated the part *a*. In an earlier stage it was thicker, and is now gradually becoming thinner. Fig. 2 represents the same portion of an utricle some time later; the connecting cord of mucilage has disappeared, which has resulted from its becoming gradually thinner, until it was torn across, and united perfectly with the two living portions of the cell-contents, *c* and *d*. The former, *c*, is now a defined, ellipsoid portion of contents, altogether free, and coated over its whole surface with a thin layer of homo-

geneous, colourless mucilage. The next and most important change which will occur in it is the appearance of an enveloping layer of membrane.

In fig. 3 is also represented a portion of an old utricle of *Bryopsis Balbisiana*. With the decaying and dissolving contents (chlorophyll, starch, and mucilage) occur small and large cells in various stages. Some are very small, and do not differ in appearance from a drop of mucilage (*a*, *a*); others are somewhat larger, finely granular, greenish, and already exhibit a delicate membrane (*b*, *b*); others again are tolerably large and green, with a distinct membrane (*c*, *c*).

Under the head of free cell-formation without a visible nucleus, the origin of the germ-cells (spores) of the Zygnemaceæ (*Spirogyra*, *Zygnema*, &c.) must also be mentioned. The facts of the case are well known; that two cells unite together (conjugate); that the septa of the point of junction become dissolved; that the contents of the two cells separate from their walls, and, either in the cavity of one of the two cells, or in the tube connecting them, become agglomerated into a globular or ellipsoidal mass, which becomes the germ-cell. All that observation shows, in reference to the last proceeding, is, at first, a mass of green cell-contents, with a definite outline, and subsequently the same mass of green contents inclosed in a membrane. There may be two hypotheses as to the formation of this membrane: 1, that it originates in the place where it first becomes visible on the surface of the contents; 2, that it originates as a minute cell in the interior, and, as it increases in size, gradually absorbs the contents.

In favour of the first assumption speaks, in the first place, the analogy with the abnormal cell-formation in *Bryopsis*, *Conferva*, &c., where the membrane is in like manner formed over the surface of the contents. Moreover, an additional support is derived from the circumstance that we can see nothing of any little cell in the interior, or of the alterations in the contents (solution and

reorganization of the solid structures, such as chlorophyll and starch), which must necessarily be connected with it. But that hypothesis is placed beyond all doubt by the following fact. It is well known that the union of two cells, and the mixture of their contents, do not always take place. Sometimes a cell produces a germ-cell from its own contents, when it either forms no conjugative branch, or when this does not meet with another with which it can become united. In the latter case the contents separate from the interior of the wall, and move toward the blind prolongation. Arrived there, any further advance being prevented, they become transformed into a cell, and indeed exactly of the form which they possess at this time: this happens in *Zygnema stellinum* (pl. II, fig. 4). Sometimes it happens that two cells communicate by a connecting tube, but the contents of the two cells do not become united. Then two germ-cells originate, one of which is ellipsoidal or globular, while the other exhibits the form possessed by the contents, which had already begun to move before they came to a state of rest and cell-formation (pl. II, fig. 6, in *Zygnema stellinum*). In both the cases here described, it must inevitably be assumed that the membrane originates on the surface of the contents. If these cells were formed of minute size in the interior, they must, in their ulterior development, retain their original globular or ellipsoidal shape, like all cells which originate and become developed in a free condition.

Schleiden* is inclined to attribute a different mode of origin to the germ-cells of *Spirogyra*, as he says: "In the already irregularly agglomerated cell-contents, I almost always found a delicate cell, which I cannot but regard as the true spore, around which the green and granular mass is merely applied, forming a false membrane around it, or which gradually absorbs this mass into its interior. Perhaps the . . . . . Cytoblast . . . . . .

* Grundzüge der wiss. Botanik, ii, p. 31 (first edition).

is the producer of the proper spore-cell." I suspect that Schleiden has observed a peculiar and enigmatical cell- or utricle-formation, which occurs in *Spirogyra*, and of which I shall hereafter take especial notice. This cell is neither the rudiment of a germ-cell, nor the germ-cell itself, nor is it produced from the nucleus of the cell. It appears to me that the cell-nuclei which lie in the centre of the cells of *Spirogyra* do not play any important part in the origin of the cell. They are often visible until the cell-contents accumulate into a ball, then they disappear; but they are by no means hidden in the contents, since if they are still visible in the later stages, they are on the surface of the green contents. I have therefore no doubt that the nucleus of the parent-cell becomes dissolved before the contents are transformed into a germ-cell. Besides, it is not evident what *two* nuclei should do in the formation of *one* cell, each conjugating cell having one nucleus. In pl. II, fig. 5, some cells of *Spirogyra quinina* are figured, in which germ-cells are formed without conjugation. In two of them the nucleus is seen on the surface of the contents; in the third it has disappeared.

I mentioned also another free cell-formation, without visible nucleus, where the observation in like manner affords a tolerably certain conclusion. This is the origin of the sporangia in *Achlya prolifera*. I have already alluded to this point in the first part of this essay,* in reference to the so-called division of cells. *Achlya* furnishes remarkable facts, both on parietal and free cell-formation, so that I will give some figures of it. In the clavately swollen ends of a branch are formed usually one, more rarely two or three sporangia. If there be two or three (Pl. III, figs. 5 and 6), these originate by free cell-formation; if there be merely one, it originates sometimes through free (fig. 3), sometimes through parietal, cell-formation (fig. 7). When the sporangia originate by free

* Ray Society's Translation, p. 279.

54988

cell-formation, the first process is the formation of one or more heaps of mucilage-granules, according as one or more cells are to be produced. At first these heaps have no definite boundary, but pass insensibly into the remaining mucilaginous contents of the cell. Subsequently the outline becomes more sharply defined, they are surrounded by ray-like circulation-filaments (fig. 1). The outline becomes still sharper, and then but a few filaments remain (fig. 2). At length the surface of the heaps of granules becomes smooth, and now an inclosing membrane gradually makes its appearance (fig. 3). Has this membrane originated on the periphery of the granular accumulation, or has it been formed in its interior as a minute cell, and in growth gradually absorbed its contents from without? I am compelled to regard the former view as correct, because nothing can be seen of the latter process, even in very transparent heaps of granules. That the membrane originates on the surface of the subsequently inclosed contents is in the highest degree probable, from the analogy with the parietal cell-formation in the same plant; for while a free sporangium is forming in the interior of one clavate branch, in others the whole clavate extremity becomes a sporangium (fig. 7). Here the cell is not formed in the interior as a little free cell, but its walls originate in the very place where they first become visible. Now the two facts support each other, and in such a way that, taken together, they prove the origin of the membrane on the surface of the contents. That in the apparent formation of a mere septum, a perfect cell actually originates, lying in contact with the wall of the branch (not a mere wall), is shown by the analogy with the second case, where a perfect sporangial cell is formed at some distance from the wall of the branch. That in free cell-formation the membrane originates on the surface of the contents (not in the interior of them, around a nucleus, or in any other way), is shown by the analogy with the first case, where the cell-membrane is formed in like manner on the periphery of the contents. The dis-

tinction lies solely in this: that in the first case the whole contents of the extremity of the branch, in the second only a part of them, are converted into a cell.*

b. With a parietal nucleus.

Free cell-formation with a visible nucleus I have hitherto only observed with certainty in the embryo-sac of the Phanerogamia. The cell-formation in the pollen-tube is not yet clear to me; of those cells which form the embryo and the suspensor, I rather imagine that they originate through parietal cell-formation; of those cells which Schleiden explains as transitory cells, I am still doubtful whether they are actual cells, or not rather mere nuclei.

When the formation of the endosperm-cells takes place in the embryo-sac, the fluid contains the following structures:

1. Cells with granular contents, and a perfect nucleus, with evident nucleoli.
2. Mucilage-granules.
3. Perfect nuclei, with evident nucleoli.
4. Minute homogeneous globules of mucilage.
5. Larger homogeneous globules of mucilage, with a globular cavity.
6. Larger homogeneous globules of mucilage, with a smaller concentric or excentric ring.

* In the sporangium which has originated in the above ways, two kinds of cells may be formed, either larger, immoveable, globular spores, with a tough membrane, or smaller oval cellules, with a delicate membrane, which move about actively either already inside the parent-cell or, and especially, after they have been set free. To this end the sporangium grows out into one or more processes (figs. 4, 6, 8), which open at the point and allow the cellules to escape. I formerly believed that even a third kind of cell originated in the sporangium, namely, smaller cells with delicate walls like the moving cellules, but exhibiting no motion, and capable of germination. Whether this third kind actually exists, or whether they are identical with the moving cells, and again, whether these are capable of germination, I must leave open, since the latter has been stated to be the fact by several observers, till further researches have been made.

7. Mucilage-globules, of equal size with the preceding, partly homogeneous, partly very slightly granular, with a cavity and a nucleolus contained in it.

8. Like 7; but with several cavities, and as many nucleoli.

9. Like 7, with one or more solid nucleoli, and no cavity.

10. Larger homogeneous or slightly granular mucilage globules, of clearer, more transparent substance, with or without cavities, with or without nucleoli.

11. Clear vesicles, of the size of 10, with or without nucleoli.

12. Mucilage-globules, like 10, or utricles, like 11, surrounded by a thin layer of homogeneous mucilage, which is usually thinner on one side than on the opposite.

13. Like 12; the mucilaginous layer has considerably increased in size on one side, become somewhat granular, and displays a very indistinct membrane on its periphery

14. Like 1, namely, distinctly perfect cells, with perfect nuclei and distinct nucleoli.

These are the principal and most frequent forms of organization that are found in the fluid of the embryo-sac, and which are of importance in the processes which go on. A quantity of intermediate stages between the various forms here enumerated are rather calculated to confuse the vision and judgment than to make a process clear through a complete history of the gradual development. Observation of these matters has to strive against two obstacles, which appear to me almost insurmountable: one depending on the fact that partial changes ensue very rapidly in the solid portions of the contents, especially when water is applied; the other, that the different stages of development are all mixed together, and thus, without the help of extraneous characters, are necessarily judged of merely by their own individual aspect.

Schleiden, it is well known, has interpreted the phenomena in this way: that a number of mucilage-granules become confluent to form nucleoli; that the nucleoli

become conglomerated with other mucilage-granules, so as to produce a nucleus, and that around the nucleus is formed a membrane, which retreats from the nucleus on one side through the absorption of fluid.

Now as to the *mucilage-granules*, which lie in the effused fluid, I believe that they are derived, in great part, from the destroyed endosperm-cells, and that they do not at all contribute to the formation of the nuclei. In the embryo-sac, where cell-formation is commencing, I often find but little, often no granular contents; these increase with the fuller development of the endosperm-cells, and with the cessation of cell-formation. This circumstance already makes the origin of the nuclei from mucilage-granules very improbable.

Again, I was never able to observe a confluence or conglomeration of mucilage-granules, and the production of a nucleus therefrom. The solid portion of the cell-contents certainly concreted into larger or smaller masses, especially when water was added. Sometimes only a few mucilage-granules, sometimes mucilage-granules and nuclei, sometimes large portions of the firm granular contents became united; a homogeneous mucilage was always the connecting medium. This, however, does not happen through any organic process, but because the mucilage coagulates. The conglomerated masses do indeed exhibit, like all coagulating mucilage, a definite outline, and, when they are small, sometimes present a striking resemblance to nuclei or young cells. But they are often actually seen to be formed, in the same way that they have been formed here, when the mucilage of any cell flows out into water.

Besides the mucilage-granules, we must likewise leave out of consideration, in cell-formation, the *clear vesicles*, which might easily be taken for nascent cells, but which are found in almost all homogeneous and rather fluid mucilage. They appear to me to be minute drops of some watery fluid (water?), which have separated from thicker, mucilaginous fluid of the cell. In most cases the

mucilage exhibits an equal density up to the border of the drop of water, so that where the water commences the mucilage appears as if cut off from it. Sometimes it is denser at the borders of the drop of water, and seems to form a proper membrane around it. Probably this is the consequence of a lengthened action of the water upon the mucilage. In any case the watery vesicles go no further; certainly undergo no organic changes.

All *perfect nuclei* lying in the fluid must also be excluded in the consideration of cell-formation. They are wholly absent at first, and multiply in proportion to the number of fully-developed endosperm-cells contained in the embryo-sac. They are the nuclei of these cells, and become free, with the granular contents, through their destruction. These nuclei are very apt to lead the observer astray, since they are not capable of the subsequent stages of development.

Small, globular drops of perfectly homogeneous mucilage, with defined outline, are absolutely constant phenomena in the process of cell-formation in the embryo-sac. They vary from ·001-·004 of a line, and are distinguished from the mucilage-granules, even in the earliest condition, by a perfectly globular form and smooth surface. The mucilage-globules are never absent; they always constitute the first stage of cell-formation (pl. II, fig. 7, *a*, *b*, *c*; 8, *a*). They exactly resemble the mucilage-globules which represent the nascent germ-cells in *Valonia* and other Algæ, in Lichens and Fungi.

A more advanced stage is represented by the *larger mucilage-globules, in which a smallish ring is inclosed, while the whole globule possesses an uniform consistence* (fig. 7, *d*, *e*, *f*). The inclosed ring may appear *clearer* (fig. 9, *a*) or *denser* (fig. 9, *b*) than the outer part of the globule. There can be no doubt, and the further development also confirms it, that the mucilage-globule is a cell-nucleus, the inclosed ring a nucleolus. How have the nucleus and nucleolus originated? This is a question which I cannot answer from direct observation on cell-

formation in the embryo-sac. Other grounds, however, which exist in the phenomena exhibited in the propagation of the nuclei, render it probable, in my opinion, that the nucleolus originates first, and the nucleus subsequently, around it.* In that case, those little homogeneous mucilage-globules, first visible, would have to be regarded as the nucleoli.

At this stage of development we find, as a rule, a homogeneous nucleus inclosing a homogeneous nucleolus. *Through injurious external influence, a hollow space round the nucleolus is produced.* This change occurs during the examination. Fig. 9 represents such a nucleus, immediately after the fluid of the embryo-sac had been brought under the microscope. It soon acquired the aspect *d* (fig. 9). This appearance of a hollow space round the nucleolus is observed both when the fluid of the cell is diluted by the addition of water, and when it is brought on the stage without water, and becomes denser through evaporation. The cause of this phenomenon appears to me to lie in the fact, that through the action of the *slightest* possible unfavorable influence from without, the mucilage of the nucleus, as well as that of the nucleolus contracts, and they are thus separated from each other. If the action be at all strong, the nucleus and nucleolus contract into a dense, solid body. Care must therefore be taken not to mistake abnormally altered nuclei, such as are drawn in fig. 9, *d*, for cells with nucleus and nucleolus, with which they may very readily be confounded.

Other nuclei contain two, three, or four nucleoli (fig. 7, *g*; fig. 8, *c*; fig. 9, *e*). These nucleoli are also sometimes of the same consistence as the nucleus, sometimes they are denser, at others not so dense. In abnormal alteration of the nuclei, a hollow space presents itself to notice around each individual nucleolus. Fig. 9, *e* and *f*, represent such a nucleus before and after alteration.

* See the Essay on the Utricular Structures in the Contents of the Vegetable Cell.

These forms with two, three, or four nucleoli *seem* to prove that the nucleus generally originates before the nucleoli. Since no distinction is evident in the nucleoli, one is inclined to regard them all of equal value; and since some of these nucleoli certainly originated after the nucleus, one is led to assume the same of all. I believe, however, the assumption that *one* of these nucleoli originated before the nucleus and produced it, and that the rest were formed subsequently, may be warranted by the analogy with cells. In cells also we sometimes find several nuclei, a primary and one or two secondary nuclei.* Therefore, since both the life of the nucleus with the life of the cell, and the relation of the nucleolus to the nucleus with that of the nucleus to the cell, exhibit so great analogy, we may reasonably assume, that when a nucleus contains several nucleoli, one of them is the primary, which originated prior to the nucleus, while the rest are secondary nucleoli formed within the nucleus.

The nuclei have now attained a definite magnitude. Their membrane may sometimes be seen indistinctly on their periphery. Their mucilaginous contents are either homogeneous or very slightly granular, of variable density. The substance of the nucleoli is generally denser than that of the nuclei, sometimes of equal, at others of a less, degree of density, so that in the last case the nucleoli appear as clearer spaces in the denser contents of the nuclear vesicle.

Subsequent stages exhibit *nuclei*, like those just described, *with a thin layer of homogeneous mucilage*. This layer is usually much thinner on one side than on the opposite (fig. 8, *d*). More rarely it is equally thick on all sides; which may be ascertained from the fact, that, in rolling, the nucleus always retains its central position (fig. 8, *e*). The mucilage is perfectly homogeneous, distinctly defined externally, and bounded by a somewhat darker line. As yet I can discover no membrane. The mucilage

* See Part I of this Essay. Ray Society's Translation, pp. 242 et seq., and pp. 247 et seq.

is mostly somewhat more dense than the substance of the nucleus; sometimes it is brighter than the latter.

The mucilage surrounding the nucleus now continually increases in quantity; the nucleus is always distinctly visible, situated at the periphery (fig. 8, *f*). There are, however, isolated exceptional cases here, where the nucleus is free, and more or less removed from the circumference.

The mucilage then becomes evidently granular, and a distinct membrane is to be made out upon its surface (fig. 8, *g*). The latter frequently becomes visible even when the contents are still homogeneous. In this stage, as in the preceding, the nucleus is mostly less dense than the surrounding mucilage, and therefore appears like a clearer space. The cell is now visibly formed. Whether the membrane first originates at the time it becomes visible, or had originated at a still earlier period, can scarcely be ascertained by observation. The latter appears to me probable.

According to Schleiden, the cell-membrane originates immediately on the surface of the nucleus; it absorbs watery fluid by endosmose, and expands; the nucleus remains attached on one side of the cell; the cell is a fine, transparent vesicle; its contents a watery fluid; and appear merely as a hollow space between the nucleus and the granular mucilage of the embryo-sac, which is pushed backward by its expansion.* Schleiden adds, that the cells become wholly dissolved in a few minutes in distilled water, so that only the nuclei remain. I confess that I have never seen such very clear and transparent cells. In most cases I find the contents of the cells more dense and darker than those of the nucleus; rarely clearer, but even then always either homogeneously mucilaginous or finely granular. In like manner, I did indeed see various effects on the young cells and their contents produced by the action of water, but never a solution.

* Müller's Archiv, 1838. [Schleiden has changed this opinion in the latest edition of his 'Principles of Botany' 1849). See Appendix to Dr. Lankester's Translation.—A. H.]

I will here mention another phenomenon which I observed a few times. I do not think that Schleiden has allowed himself to be deceived by this; yet others, who may also observe it, may easily suppose it to be the process of cell-formation as described by Schleiden, to which it bears great resemblance. Nuclei which have attained a considerable size, absorb water by endosmose. The membrane of the nucleus detaches itself on one side from the contents, the interspace becoming filled with water. The comparison with a watch-glass is here not inapt. In some cases, the membrane continues to expand, suddenly bursts, and disappears. In others, this expansion goes on to a variable extent, and ceases when the force of the endosmose and the elasticity of the membrane come into equilibrium. The membrane remains visible and is not dissolved. (See fig. 9, *i*, *k*, *l*, *m*; in *h*, *i*, *k* the same nucleus is represented previous to the action of the water, and in two stages after the operation of endosmose has begun.)

If the nuclei contain only one nucleolus, one may readily suppose them to be cells, and the hollow space round the nucleolus to be the nuclear vesicle (fig. 9, *i*, *k*). Those forms, with two or three nucleoli (fig. 9, *l*), however, prove that it is inside the nuclei that the hollow spaces have been formed through the action of water, as is the case in the nucleus represented in fig. 9, *c-g*. The contents of the nucleus are pretty sharply defined where they join the water. The outer circumference of the nucleus exhibits a dark line, which is formed by the delicate membrane lying close upon the contents, and which, therefore, is lost when this membrane has become detached from the contents (fig. 9, *k*, *l*, *o*). These facts furnish a new proof that the nuclei possess a membrane and are vesicles.

The young cell appears at first as a layer of mucilage surrounding the nucleus. Subsequently a membrane becomes visible on the surface of the mucilage. Consequently the cell is at first, besides the nucleus, quite filled

with mucilage. When the cell expands more, it becomes hollow in the interior. The mucilage remains on the wall as a thin layer, and forms a coating over the whole internal surface. This is the *mucilaginous layer* which I have described in the Algæ,* and which Mohl† has named the "*primordial utricle*," regarding it as a structure proper to all cells. The mucilaginous layer is usually thicker at the place where the nucleus of the cell lies, than over the rest of the wall. Not unfrequently the nucleus lies wholly imbedded in the mucilaginous layer. Schleiden thought that it was inclosed in a duplicature of the cell-wall. But this is certainly incorrect, and is best refuted by the fact, that the nucleus may become detached, with the mucilaginous layer, from the membrane of the cell.

Mohl conjectures that the first thing formed around a nucleus is the primordial utricle, and that the membrane does not originate until after this. The statements in regard to this are, however, too vague, and made without consideration of cell-formation in the embryo-sac, so that no minute discussion is necessary for the criticism of the phenomena in question. I merely remark that I see the origin of the mucilaginous layer (primordial utricle) on the internal surface of the cell in the endosperm-cells, in the same manner as in all other cells where new contents are formed. The mucilage at first fills the whole cavity of the cell, and subsequently merely lines the walls as a thin layer. The mucilaginous layer is, therefore, a *secondary* phenomena in the *origin of the cell-contents.*

c. Of free cell-formation as a general law.

Now that I have separately brought forward the facts which are at my command respecting free cell-formation, I will briefly collect and compare them, in order to

* See Part I of this Essay. Ray Translation, p. 268.

† Botan. Zeit. 1844. (Translation in Taylor's Scientific Memoirs, vol. iv, p. 91.)

deduce a general law, and, in addition, to point out some essential differences within the bounds of this law.

The phenomena which accompany free cell-formation may be seen with the greatest certainty in the origin of the germ-cells of *Zygnema*, the sporangial cells of *Achlya*, and the larger cells produced by abnormal formation in *Bryopsis*, *Conferva*, and other Algæ. Here a portion (in *Zygnema* the whole) of the contents becomes isolated, acquires a globular or ellipsoidal form, and produces a perfect closed membrane all over its external surface. In the prevalent opinion on free cell-formation, it has been hitherto assumed that the membrane originates around a nucleus. In the cases mentioned here there cannot be any doubt that the membrane originates around the contents. It was further assumed that the membrane was formed first and the contents subsequently. Here, however, the contents are decidedly primary and the membrane secondary.

The mode of origin of the endosperm-cells in the embryo-sac comes next to these facts. Observation shows here, first a nucleus, then a layer of mucilage which surrounds this nucleus, lastly, a distinct membrane which incloses the mucilage together with the nucleus. The phenomena accessible to observation leave the place and epoch at which the membrane originates undecided. The assumption that it is formed immediately around the nucleus is, therefore, still within the bounds of possibility. But it would appear to me uncalled for and superfluous, since no fact nor analogy are in its favour.* If we assume, on the other hand, that a definite quantity of mucilage collects around the nucleus, and that the cell-membrane originates around this mucilage, the assumption on the one hand fully meets the appearances in the

* Schleiden's observations certainly are contradictory to my representation and interpretation, and these points are still open. Formerly I thought that I also saw cell-formation round the nucleus. I have studied the processes occurring in the embryo-sac repeatedly, for several years, and in different plants; with more accurate observation, however, I can no longer find any condition which perfectly agrees with Schleiden's representations.

case in question; and on the other, connects itself, through analogy, with other facts, as in the cell-formation already mentioned, in *Achlya*, *Zygnema*, and other Algæ, as well as with the parietal cell-formation, where the membrane is likewise produced on the surface of the contents.

The third type of free cell-formation still remains, in the origin of a number of germ-cells of Algæ, Fungi, and Lichens. Here observation at first discloses to us extremely small globular masses of mucilage. They become larger, granular, and at last an inclosing membrane may be made out. Actual experience is again insufficient to furnish a certain determination of the question when and how the membrane originates. It seems to me safest to take the simple explanation of the facts which is first suggested by what we see, especially since they can in this manner be most readily brought into agreement with the other facts. I therefore assume here, that the membrane is formed round a collection of the mucilaginous contents. Whether this happens earlier or later, seems to be all one; but it is probable that the membrane actually exists some time before it is distinctly visible. The observations on free cell-formation therefore *require*, they partly *allow*, the assumption, that the *membrane is produced on the surface of the contents*. This hypothesis must, since no facts and no analogy are opposed to it, hold as a universal law. The *contents*, therefore, are *primary*, in the cell, the *membrane* is only *secondary*.

In the production of the endosperm-cells a nucleus exists. The nucleus originates first. Subsequently, a layer of mucilage accumulates on its surface. Probably it is the attractive force of the nucleus which draws to it a portion of the contents of the parent-cell. That the nucleus does possess such a power is known from many facts. In almost all cells in which a nucleus exists, a portion of the contents of the cell become collected on its surface. Consequently, we may define cell-formation in the embryo-sac in the following way:—*A nucleus origi-*

nates, which attracts a small portion of the mucilaginous contents, and becomes wholly clothed by it: on the surface of the mucilaginous layer the cell-membrane originates.

In the other cases of free cell-formation, nothing can be seen of nuclei during the whole process. Either no nucleus really exists, or it withdraws itself from vision, through relatively minute size, or agreement of density with the density of the contents of the young cell. In the first case we must assume, that a definite portion of the contents of the parent-cell may independently become individualized and converted into a cell. In the second case, the process would be the same as in the endosperm-cells. In my opinion a rigid distinction must be made between normal and abnormal cell-formation, in solving this question. By normal cell-formation I understand such as is necessarily connected with the vegetative and reproductive processes in a plant, and which always proceeds according to laws definitely laid down for each plant. By abnormal cell-formation, on the other hand, I understand such as is not directly and necessarily connected with the vegetative and reproductive processes, and must always be regarded more or less as produced by the action of external influences interrupting the regular course of the life of the cell.

As to the abnormal cell-formation in the cells of Algæ, I am convinced that no nuclei ever take part in it. For this kind of cell-formation is united by every possible intermediate stage, with a process in which the formation of nuclei cannot enter into the question. In the first part of this Essay* I have mentioned a partial formation of membrane where, in consequence of disturbing external influences, the mucilaginous layer is retracted in places from the cell-wall, and becomes coated with new pieces of membrane. This process is of course independent of the influence of any nucleus. I, at the same time, stated that the mucilaginous layer sometimes becomes detached

* Ray Translation, pp. 268 et seq.

over large surfaces, or even entirely (as in *Bangia*) from the cell-wall, and produces a membrane on its surface; moreover, that sometimes the mucilaginous layer divides into separate portions, and produces several perfect cells. It is clear that in this case, again, we cannot think of the formation of a nucleus for the production of the cells. These facts stand in direct connexion with those above described in abnormal free cell-formation. The mucilaginous layer separates from the wall, divides, and forms several larger or smaller cells. These vary in size and contents, from large cells containing chlorophyll and starch, to the most minute cells inclosing merely homogeneous mucilage. This mode of cell-formation varies, besides, from that condition in which the whole cell-contents partly form new cells, the remainder being dissolved, to that in which merely a small portion of the contents forms one or more small cells, while the remainder is unaltered. These transitions show that all the phenomena of abnormal cell-formation are related to *one* law, and that since the formation of nuclei is inadmissible in some cases, it must not be assumed in the rest.

In those cases where free cell-formation takes place normally, as in the origin of the germ-cells in Algæ, Lichens, and Fungi, and of the sporangium in *Achlya*, we can see nothing of a nucleus. The fact, as presented directly to us, with the assistance of the amplifications our present optical instruments effect, may in the same way be most simply explained thus: that larger or smaller portions of the contents at once become individualized, and acquire a membranous investment. But the circumstance that a nucleus may sometimes be perceived subsequently, in the germ-cells which have originated by free cell-formation, seems to me to speak against this. I have seen it in *Erysibe*, *Achlya*, *Peziza*, *Coleochæte*, &c.; and it appears to me to be also present in the germination of the Zygnemaceæ. Two explanations may be given as to this nucleus. Either it is a *primary* nucleus, around which the cell originated, or it is a *secondary* nucleus

which has been formed as an after-growth in the cell. We are acquainted with such secondary nuclei in the parent-cells of spores and pollen-granules, and in the spore- and pollen-cells themselves.* In these, however, there is also a primary nucleus. The two nuclei lie side by side in their cell; or the primary nucleus becomes dissolved when the secondary is produced. In the cases referred to, the primary nucleus is parietal, the secondary free. Now, as regards the nuclei in the germ-cells of the Algæ, Lichens, and Fungi, in some I found a distinctly parietal position. I conjecture, therefore, already on these grounds, that they are primary nuclei, and, consequently, that a nucleus exists in the origin of the germ-cells. This conjecture is supported by another reason. In the section on the nucleus,† I demonstrated that if any conclusion from analogy at all be permitted, it must be assumed that every vegetable-cell possesses a nucleus, at least in the early stages of its existence. It is, therefore, in the highest degree probable that a nucleus is present in the cell originating by normal cell-formation, and this at the actual time of its origin. This argument is still further borne out by the fact that sometimes, in plants where no nucleus is visible in the formation of the germ-cells, all the succeeding cells are developed under the influence of nuclei. Now it seems to me very improbable here that the vegetative cell-formation should take place through nuclei, and the reproductive cell-formation without, that, consequently, the lower cell-formation should present greater complexity, and the higher be the more simple. It is further to be remarked, that the assumption that germ-cells originate like endosperm-cells around nuclei, may be connected with the visible phenomena without stretching any point. In both places, globules of mucilage first present themselves, which gradually enlarge, and at last appear as granular cells. In the endosperm-cells, the nuclei may be distinguished and recognised as such,

* Part I, Ray Translation, p. 247. ‡ Ibid., pp. 219 et seq., and 246.

at a very early period. In the germ-cells, the nuclei are distinct, as such, sometimes never, sometimes only in the fully-developed condition of the cell. Since the nuclei can be distinguished sufficiently early in the endosperm-cells, it is also possible to observe their relation to cell-formation. Since the nuclei of the germ-cells cannot be distinguished until a late period, their relation to cell-formation cannot be made out by direct observation. This is the more conceivable, that the endosperm-cells are many times larger than the germ-cells, and their nuclei than nuclei of the latter. Besides this, endosperm-cells do also occur in which the presence of a nucleus, and its cooperation in the cell-formation, cannot be distinctly seen. This is especially the case when the contents of the nucleus and those of the young cell are homogeneous and of equal density. What I have stated is, I think, sufficient reason why the apparent want of nuclei in the free formation of germ-cells cannot be maintained as a proof of an actual absence of these bodies.

Normal free cell-formation thus comprehends, according to my views, the following essential and regular periods: *A nucleus originates in the contents of the parent-cell. This accumulates on its surface, by attraction, a greater or smaller quantity of the contents of the parent-cell, which, at least at the periphery, consist of homogeneous mucilage. This portion of the contents becomes coated by a membrane over its entire surface.*

The variations which occur within the limits of this identity, refer either to the nature of the portions of contents which become individualized, or the relation of the secondary cells to the parent-cell. The portion of contents which become isolated, exhibit *chemical* and *morphological variations.* They are composed either of homogeneous, colourless mucilage; of homogeneous colourless mucilage mingled with colouring matters; of granular mucilage, or granular mucilage mixed with colouring granules and starch-globules.

The relation of the secondary cells to the parent-cell

depends either on the *share which the parent-cell bears in the production of the secondary cells, or on the physiological similarity or dissimilarity which exist between the parent-cell and the secondary cells.* In reference to the first point, it is of importance whether the *whole contents of the parent-cell, or only larger or smaller portions of the contents, are converted into secondary cells,* and in what *number* these are produced in the parent-cell. In reference to the second point, either perfectly similar or dissimilar secondary cells may be formed in the parent-cell. Physiologically similar secondary cells are produced in *Hæmatococcus* and *Chlorococcus;* all other cells originating through free cell-formation, are more or less different in physiological respects from the parent-cell.

The question still remains, to what extent is free cell-formation met with in the vegetable kingdom? In the first part of this essay,* I limited parietal cell-formation to several families of Algæ, and the special parent-cells of the four-spored Cryptogamia and the Phanerogamia. For all the examples there enumerated, I had observations which more or less bore out the statement. Free cell-formation, on the other hand, I was acquainted with in the endosperm-cells and in the germ-cells of Algæ, Fungi, and Lichens. For all other cases, especially for all vegetative cells of four-spored Cryptogamia and the Phanerogamia, the decision depended partly on analogy, partly on some observations of Schleiden's, and of my own. I therefore concluded:—In parietal cell-formation the nucleus is, as a rule, central; in the free cell-formation in the embryo sac, the nucleus is lateral. It is probable from this, since the cells of the higher Cryptogamia and the Phanerogamia possess a lateral nucleus, that they originate by free cell-formation. The secondary cells were, moreover, figured actually free within the parent-cell, in certain cases, by Schleiden and by myself. I was satisfied, therefore, that the cells with lateral nuclei originated free.

Observation and reflection have since led me to a

* Ray Trans., p. 292.

different conclusion. In the very first place comes the question, what import may be attributed to those observations which represent the secondary cells free within the parent-cells, as Schleiden's in the germinating spore of *Marchantia*,* in the hairs of the ovary of *Lupinus*,† in the terminal shoot of *Opuntia*,‡ in the pollen-tube, and in other cells,§ and my own in the apex of the root of *Lilium*.‖ As to my own earlier investigations, they belong to an epoch (autumn 1841, and spring 1842,) when I was yet unacquainted with the mucilaginous layer. When I discovered it, in the summer of 1842, at Naples, in Algæ and Florideæ, and subsequently refound it in other vegetable-cells, I soon became convinced that my earlier researches were doubtful, since that which I had held to be the cell-membrane might in every case have been the mucilaginous layer.

With regard to the facts published by Schleiden, I likewise believe that the explanation given by him is by no means placed beyond all doubt. In the first place, cell-formation in the pollen-tube cannot prove anything for other cell-formation; since here two thoroughly different kinds of cell-formation, one of which is transitory while the other produces the embryo, have not yet been nearly sufficiently discriminated. The cell-formation in the spore of *Marchantia*, I must, from certain researches of my own on the germination of the Hepaticæ, hold to be incorrect; and conjecture that a confusion has occurred with the accidental formation of utricles, such as sometimes happens in cells. With respect to the rest of the observations published by Schleiden, it must be borne in mind that he also makes no distinction between cell-membrane and mucilaginous layer; so that the interpretation is always possible, that the apparently free secondary

* Müller's Archiv, 1838, Tab. iii, figs. 19, 20.
† Acta Ac. C. L. C. Nat. Cur., vol. xix, p. 1, pl. x, fig. 38 *e*.
‡ Mém. de l'Acad. Imp. d. Sc. de St. Pétersbourg, VI Serie, vol. iv, pl. viii, fig. 9.
§ Grundz. 2d Ed. pl. i, figs. 12 and 16.
‖ Linnæa, 1842, Pl. ix, figs. 30, 31.

cells have been merely the *contents* of secondary cells contracted through external influences. Two reasons especially strengthen this opinion in my mind. In one case Schleiden figures three secondary cells in one parent-cell. Now, as I shall hereafter show, it is an universal law that in the formation of the cells of tissues only two secondary cells are formed in each parent-cell. If, then, one wall have been overlooked in consequence of the alteration of the contents, so readily may the other. Schleiden further says that he has often seen two cells inside one cell,* especially after the *application of nitric acid.* This is in contradiction with the observation he made, that the young cell-membranes are wholly dissolved in distilled water, in a very short time.† If this will happen in water, it will certainly happen much more quickly in nitric acid. It is in the highest degree probable from this, that Schleiden saw merely the contracted *contents*, not the young cell and its membrane; and, moreover, in that condition in which the action of the acid has already made the delicate membrane of the secondary cells indistinct, while the older and firmer membrane of the parent-cell still remains visible.

Since then a better appreciation of the membrane, and the recognition of the mucilaginous layer, rendered all earlier observations uncertain, I instituted a new series of investigations. If the tissue of the higher plants were really produced by free cell-formation, this could only be proved by seeing the young free cells, free in uninjured and unaltered parent-cells. I must confess that I never have arrived at this. In most cases this is, indeed, no proof at all of the contrary; since admitting a free cell-formation, it would, in my opinion, be unlikely, in the majority of cases, that the delicate membranes should be seen in the but slightly transparent mucilage, previously to their union to form a wall. On the other hand, I believe that in certain other instances it might possibly have

* Grundz. 2d Ed., p. 202. † Müller's Archiv., 1838, p. 145.

happened, that the young free cells should have been seen, —in some when the parent-cells were larger, and filled with granular contents (as in many hairs when their development is beginning, e. g. of *Tradescantia*); in some when the parent-cells, of considerable size, contained a homogeneous and tolerably transparent fluid (as in the young rind and bark of many plants); in others when the parent-cells were tolerably large, and more or less filled with coloured, homogeneous or granular contents (as in *Callithamniaceæ*). But in no case could I see the young free cells inside the parent-cells. The formation of the cells of tissues in the higher Cryptogamia and the Phanerogamia, displayed to me nothing but either merely a dividing wall, or two nuclei and then a wall between them, or a larger nucleus which divided into two nuclei, and then a septum formed between these.

In consequence of these researches I have come to the conclusion, that all vegetative cell-formation is parietal. This conclusion is supported on the one hand by the facts observed, on the other by analogy. Among the facts, some do not contribute to the proof; others make the parietal cell-formation probable; a few can be explained by it alone. In *Griffithsia corallina** (pl. III, fig. 9), the parent-cells are very large, as much as ·080 of a line long and more, and sometimes of almost half that breadth. The granular contents lie upon the wall; the interior is filled with clear, colourless fluid. The cell divides into two unequal cells, at the apex, by a cross wall (fig. 10): an upper cell, small, disc-shaped, and wholly filled with granular contents (*a*), and a large lower cell (*b*), resembling the parent-cell in all its parts. If the two secondary cells were formed free, the lower, especially, must be seen during its development, and changes in the parietal firm contents be perceived, when this became dissolved in the parent-cell and reorganized in the secon-

* *Griffithsia* belongs to the *Florideæ*; the *Florideæ*, however, have not a natural relationship to the Algæ, but with the Hepaticæ and Mosses. They also, like these, possess parietal nuclei in the cells.

dary cell. The appearances are the same here as in the parietal cell-formation of the Algæ. From this indubitable example we have numberless intermediate stages to those cases in which no evidence is afforded, either for or against. The succession of states and the transitions show, however, that the same explanation must come into application for all cases.

The conclusion that all vegetative cell-formation is parietal, is also supported by analogy. The parietal cell-formation of Algæ and special parent-cells occurs, as a rule, with central nuclei. But to this rule there are some exceptions, when the parietally originating cells possess a lateral nucleus.* In the vegetative cell-formation of the higher Cryptogamia and the Phanerogamia, the nucleus is, as a rule, lateral; yet it appears to me that, in exceptional cases, it may be free also. The appearances in the Algæ and special parent-cells on the one hand, and in the cells of other plants on the other, are essentially the same, only they present themselves much more distinctly in the first, and much more definitely require to be explained as parietal cell-formation.

Parietal and free cell-formation would, according to my views, extend through the vegetable kingdom within the following bounds:

Parietal: the vegetative cell-formation of all plants, further, the reproductive cell-formation of many Algæ and Fungi. Free: the reproductive cell-formation of most (not all) *plants*, namely, the *germ-cell formation of many Fungi, many Algæ, and of the Lichens; the formation of the spores inside the special parent-cells in the four-spored Cryptogamia* (*?*), *the formation of the pollen-cells inside the special parent-cells in the Phanerogamia* (*?*), *and the formation of the endosperm-cells in the Phanerogamia.*

The cells which have originated by parietal cell-formation possess central nuclei (in most Algæ, and generally the special parent-cells), *or lateral nuclei* (in most Fungi,

* Part I, Ray Trans., p. 552 et seq.

in the Cryptogamia from the *Florideæ* upward, and in the Phanerogamia). *The cells which have originated by free cell-formation contain, as a rule, a lateral nucleus, rarely a central nucleus* (the germ-cells of certain Algæ).

V.—ON CELL-FORMATION IN GENERAL.

Now that I have discussed, in the third section of this essay, *parietal*, and, in the fourth, *free* cell-formation, I will compare these two processes, and thence deduce a general law.

In *parietal* cell-formation *the contents of the parent-cell divide into two or more portions. Around each of these portions of cell-contents a perfect membrane is produced, which, at the moment of its origin, is in contact partly with the wall of the parent-cell, partly with the corresponding wall of its fellow secondary cell or cells.*

In *free* cell-formation *a greater or smaller portion of the contents becomes isolated, or even the whole contents of the cell. On the surface of this is formed a complete membrane, altogether free at its outer surface* (in contact neither with the wall of the parent-cell nor those of its fellow secondary cells.

Cell-formation includes two stages; the first is the *isolation* or *individualization of a portion of the contents of the parent-cell;* the second consists in the *origin of a membrane around individualized portions of the contents.* Cell-formation commences with the first, and is completed in the second stage. The complete individualization only occurs for the express purpose of *cell-formation.* The *formation of membrane,* on the contrary, is a universal phenomenon, proper to the cell generally (not merely at the moment of its origin). I will first speak of this latter.

In the first half of this memoir, speaking of the cells of the Algæ, I have noticed the mucilaginous layer which lies on the outermost boundary of the contents, and therefore close upon the surface of the cell-wall. According

to Mohl, this is of very general occurrence. From my own researches, I believe that I may venture to affirm, that, with the exception of those young cells, in which the cavity is filled with homogeneous mucilage, *the mucilaginous layer is always present in cells so long as they retain their vitality.* It is well known that the thickening of the cell-walls is effected by a deposition of new layers. These new layers are produced between the cell-wall and the mucilaginous layer. This fact admits of no other explanation than this : *that the mucilaginous layer* (or the contents through this layer) *secretes organic, unazotized molecules which form the new thickening layer.*

I have further shown, in the first part of this essay, that in consequence of disturbing external influences, in the cells of various Algæ, *the mucilaginous layer is retracted, in places or entirely, from the wall, and produces a membrane on the surface, which becomes free, and bounded externally by water.* This membrane is not merely similar to cell-membrane in outward conditions. It presents itself as such in all its characters, so that, in particular, it has the power of growing out, either to produce a radical hair (*Bangia*), or a new ramifying and fructiferous filament (*Achlya*).

Even mucilage, mixed with various other contents, which had escaped from injured Algæ-cells into water, and lay scattered in detached portions in this, sometimes presented to me a bounding layer on the surface, which I could not distinguish from the delicate membrane, such as occurs on young cells. This bounding layer is wanting to mucilage which has just escaped from the injured cell. It is evident that it was produced by the mucilage.

These three facts prove, *that organic, unazotized molecules are secreted on the surface of living vegetable mucilage, and these inclose the mucilage in the form of a membranous layer.** Whether mucilage be free or lie in contact with

* I here presume to add a remark on the term "mucilage" (*schleim*; mucus). Most vegetable physiologists use the word, partly for vegetable gelatine, partly for gum; on the other hand, Schleiden applies it to the

a membrane makes no difference as to its function. Even in regard to the secreted layer, the distinction is not essential, and exists only in so far that in the one case this is called a *membrane*, in the other a *layer of thickening*. That there is no distinction between membrane and thickening layer is proved by the formation of membrane on the surface of a partially free mucilaginous layer, in the cells of Algæ. There the newly-formed piece of membrane passes continuously into the innermost layer of thickening; or, in other words, the gelatinous deposit secreted simultaneously over the whole surface of the mucilaginous layer, appears in some places as a layer of thickening, in others as a membrane.

If we conclude from the fact that the mucilage produces membrane or layers of thickening through secretion on its external surface, and that there is no essential distinction between them—from the formation of membrane to that of cells, it follows logically *that the membrane must originate through secretion from the mucilage in all cell-formation*. This conclusion is very strongly supported by certain phenomena in cell-formation itself.

proteine-compounds. An agreement between these views would not be readily effected. In addition there is a substance which is called *schleim* by both parties; this is the homogeneous, thickish, colourless matter, forming the total contents of the young cell, and the homogeneous, denseish, colourless ingredient in the contents of old cells. If, now, *schleim* is to have the signification of one or other (ternary or quaternary) of the *chemical* substances, it is incorrect to call the last-mentioned *schleim*. For this is certainly not a pure substance, but at the least a mixture of ternary (gum and sugar) and quaternary substances (proteine-compounds). This mixed matter is of the greatest importance in the life of the cell, since it is effective in cell-formation, in the first instance fills the whole cavity of the cell, subsequently lies upon the wall as mucilaginous layer, and traverses the cavity in currents of circulation, lastly, forms the contents of many utricles. (See the Essay 'On the Utricular Structures' in this volume.) It therefore requires a special name, and since the term *schleim*, on the one side, may certainly be spared from the nomenclature of ternary and quaternary organic matters, while on the other it is already in use in the proposed sense, it would be most advantageous to name the homogeneous denseish substance of the vegetable cell-contents, composed of mingled ternary and quaternary matters —schleim. [Mohl has proposed, and Schleiden and others have adopted, a better name, *protoplasma*, which has solely a *physiological* value, confusion resulting from the misuse of a term having a chemical signification.—A. H.]

I have already remarked* that, in the *abnormal cell-formation* in the cells of Algæ, a great multiplicity of conditions occur in regard to the contents which produce the membrane, and that a continuous series of gradations exists from abnormal cell-formation to the normal phenomena of cell-life. Sometimes a free cell is formed by a small portion of homogeneous mucilage, sometimes by a larger quantity of mucilage containing chlorophyll and starch; sometimes a considerable portion of the cell-contents produce, here a membrane, there layers of thickening; sometimes the whole contents form either a perfect membrane, or partly membrane, partly thickening layer, or a complete layer of thickening. These various phenomena are all connected by a number of intermediate states, so that the necessary cause and nature must be alike in all.

Since now, in some cases (if, namely, the mucilage borders on an existing membrane or on water) it is certain that the membrane cannot originate in any other way but through secretion from the mucilage, which is afterwards inclosed, we must undoubtedly assume a like origin in the other cases, where a part or the whole of the surface of the mucilage is bounded by fluid, unazotized or azotized contents. Consequently, in free abnormal cell-formation, the membrane is formed through secretion from the portion of contents which becomes a cell, and by no means in any other way from the rest of the contents of the parent-cell.

Passing from the abnormal parietal and free cell-formation to the *normal parietal cell-formation*, we find here also that the phenomena themselves lead to that assumption through a conclusion deduced from analogy. I have already discussed this at length in the section on parietal cell-formation. The contents of the parent-cell divide into one or more portions. The new membrane originates in some places between the mucilaginous con-

* Pages 97, 99, 114.

tents and the wall of the parent-cell, in some places between the mucilaginous contents and the wall of the simultaneously-produced fellow secondary cell. Here again no other hypothesis is possible but that of the origin of the membrane through secretion from the mucilaginous contents. The surface of the contents secretes layers of thickening up to the moment when cell-formation begins. The layer secreted *at* this moment is the rudiment of the membrane of the new cell.

In *free* normal cell-formation, lastly, the phenomena, if they do not exclude every other theory, are not unfavorable to the hypothesis founded on analogy. The most indubitable case is that in *Achlya*, where the sporangium-cell sometimes originates by parietal, sometimes by free cell-formation. Since here, in the one case (in the parietal mode of origin) the membrane is produced through secretion from the contents, it is certain that the same happens in the other case. In the formation of the germ-cells of Algæ, Lichens, and Fungi, and in that of the endosperm-cells in the embryo-sac, the phenomena admit of a twofold explanation: either that the membrane is a *secretion* from the portion of contents becoming isolated, or that it is a *deposit* from the fluid of the cell surrounding the isolated portion. Schleiden and Schwann have, as is well known, maintained the latter explanation. They found an analogy for it in the inorganic crystallization, but I believe that there is no analogy to it in the region of organic processes. On the other hand, the former explanation finds its certain analogy in lignification, in abnormal free and parietal, and in normal parietal cell-formation. Thus there exists no reason why we should not assume the origin of the membrane in consequence of secretion from the contents, to be certainly established also in free normal cell-formation.

The examples of the formation of membrane, in the manner we have just seen, fall into two categories: 1, Those in which the phenomena directly require the hypothesis that the membrane is formed through secre-

tion from the contents; 2, Those in which the phenomena do not oppose this hypothesis, and at the same time do not afford the slightest probability to any other assumption. Thus no objection can be made against the conclusion from analogy, so much the less that the examples of the second category do not include any single point not found in the first category which might suggest a process of a different nature.

From the foregoing discussions I must express the definition of the *formation of membrane* in the following terms: *The cell-membrane is an investment lying upon the surface of the contents, secreted by the contents themselves.* The membrane of a cell is the product of its own contents, as well in the beginning as subsequently. It does not originate through the chemical action of one substance upon another of different kind; its formation is an organic process, and in fact a process of secretion. This theory of the formation of membrane is, as we have seen, an immediate consequence of the facts, and avoids those formal and material errors which are connected with the theories of Schwann and Schleiden, and of which I have spoken elsewhere in the definition of a cell.

The other essential epoch in cell-formation is the *individualization of a portion of the contents, which becomes transformed into a new cell.* Here again we must, at the outset, distinguish between *normal* and *abnormal cell-formation.* In *abnormal cell-formation,* the mode in which the contents become individualized does not depend on a definite law, but on mere external, accidental circumstances. Large or small, many or few, portions of contents become isolated and form new cells. The idea of individualization of portions of the contents is here altogether vague, since it gradually loses itself in the opposite process.

I have already repeatedly noticed a series of phenomena which the *abnormal cell-formation* presents in living cells. The one extreme is exhibited where a minute free portion of contents, composed of mucilage alone, becomes clothed

by a membrane; the other is where the contents of a cell become detached from the walls only in places, and produce new membrane on these places. One extreme is a perfect cell-formation; the other merely a slight alteration of the form of the cell, combined with a partial production of new membrane. One extreme is the production of a new individual cell; the other is the reorganization of the partially injured individuality.

Between the two extremes occur a quantity of intermediate stages, in which it is doubtful, in particular cases, whether the old cell persists in an altered form, or whether a new cell has replaced it. The fact is certain, but the explanation is furnished by the observer. In all those cases where the mucilaginous layer is merely detached in places from the cell-wall, and produces pieces of membrane, we always recognize the cell as the same, with partially altered form and membrane. In all those where portions of the contents become isolated, and complete their separation from one another by the formation of membrane, we suppose new cells to take the place of the parent-cell; but if the entire contents of a cell are detached from the wall, become isolated, and then form a new complete membrane, we may call this a *cell-formation*, as well as we can call it *formation of membrane*. The contents of the old and new cell are exactly the same, the walls altogether different. Is a new individual formed, or is the individual merely reorganized (through regeneration of an organ)? This case stands just midway, and admits either explanation equally well. A step toward one side (if not the whole contents, but merely a portion, become detached from the wall), or one step toward the other (if not the whole contents, but merely a portion of them become completely isolated), will strictly decide the explanation to be either reorganization of the cell, or cell-formation.

The transition occurs again in a different way. If the contents of a cell become detached from the wall in one place, and acquire a new coat of membrane over this

place, while a larger or smaller portion of the contents are lost and become dissolved, through the separation, we shall always regard a cell altered in this manner as the same. It has indeed lost a part of its contents, and acquired a partially different membrane; but the greater portion of its contents and membrane remain unaltered. On the other hand, if a very large quantity of the contents separate and disappear by solution, we may regard the remaining portion, which becomes inclosed by a membrane, as we please, either as the altered original cell, or as a new one. If the detached portion of contents, instead of undergoing solution, remain living and acquire a membranous coat, two new separate cells will have replaced the original cell. We must, therefore, assume that cell-formation takes place here. Of the three cases mentioned, the first is undoubtedly a reorganization of the individual cell; the third, undoubtedly a production of new cells; the second is either one or the other, according as it is compared with the one or other process.

The result of these considerations is: *that abnormal cell-formation cannot establish any firm and absolute definition for the process of individualization of the portions of contents for the purpose of cell-formation;* because this process is essentially uncertain, and merely different in degree from that which stands in opposition to it.*

Passing now to *normal cell-formation*, we find the process of individualization of the portions of contents connected with determinate laws. We find no phenomena here, forming transitional stages towards a different process, in any way, towards that of mere reorganization of the cell. The individualization of the contents for the purpose of cell-formation appears, in general, under four different forms:—

1. *Solitary, minute portions of the contents become iso-*

* I was compelled to establish this fact somewhat at length, because many abnormal phenomena of cell-life have already been taken as evidence in discussions on cell-formation. They are testimony for the *formation of membrane*, but not for that *of the cell* generally.

lated in the interior of the rest of the contents of the parent-cell (Formation of free germ-cells in Algæ, Lichens, Fungi, and of the endosperm-cells of Phanerogamia.)

2. *The entire contents of one cell, or of two cells connected by conjugation, unite into one free, globular, or ellipsoidal mass* (Formation of the germ-cells of Zygnemaceæ).

3. *The entire contents of a cell divide into two or more portions* (parietal cell-formation in cell-division.)

4. *The entire contents of a short branch of a cell, or of the terminal portion of a longer branch, separate from the rest of the contents of the cell* (parietal cell-formation in the so-called constriction, as, for instance, in the formation of the germ-cells of several Algæ [*Vaucheria*, &c.] and many Fungi).

The phenomena exhibited by the individualization of the contents, in normal cell-formation, are externally the same as in abnormal cell-formation. In abnormal cell-formation, external, accidental influences exert a disturbing action on the life of the cell. In normal cell-formation, the *presence of a nucleus* must be especially counted among the conditioning causes. I have demonstrated it to be in the highest degree probable that nuclei are always present both in parietal and free normal cell-formation. They are wanting in abnormal cell-formation, and in this lies the essential distinction between normal and abnormal cell-formation.

If we may presuppose the necessity of the presence of a nucleus in the normal individualization of portions of contents, the processes must be completed in the following ways, in the four forms of individualization just mentioned:—

1. One or more nuclei originate in the contents of the cell. Each of these collects the contents in its immediate vicinity upon its surface. These portions of contents are composed of homogeneous mucilage, or mucilage with which is intermingled other assimilated substances, such as chlorophyll or other colouring matters, starch, oil, &c.

Through this, free cells originate in the contents of the parent-cell. The nuclei are in some cases already visible during the individualization of the contents; sometimes they do not become visible until afterwards; in certain cases they have not hitherto been perceived.

2. A single nucleus originates, which lies in the midst of the accumulation formed by the whole contents of one cell, or of two conjugated cells. This accumulation forms a single free cell in the empty cavity of the parent-cell. The nucleus does not become visible until the development of the germ-cells to new plants.

3. Several nuclei originate in the contents of the parent-cell, distributed in a regular arrangement. Each of these individualizes the contents of the parent-cell, through attraction, with a force only limited by that of the other nuclei. At the limits which separate the field of action of each nucleus, which, *ceteris paribus*, are equally distant from each pair of nuclei, the membranes are formed. In other words, the whole contents of the parent-cell divide into just as many portions as there are nuclei; a nucleus lies pretty nearly in the middle of each portion; the portions are separated from each other by an extremely narrow space, in which each portion of contents secretes its own membrane. The parent-cell divides, by parietal cell-formation, into several secondary cells.

4. A single nucleus originates in a short branch (in the prolonged part), or in the terminal portion of a longer branch of a cell. Under its influence, the whole contents of the short branch or of the terminal portion of the longer one, separate from the rest of the contents of the cell and form a new cell, the membrane of which is partly parietal (in contact with the internal surface of the branch), and partly free (directed towards the cavity of the older cell). But the parent-cell, excepting in the loss it has suffered, remains unaltered. The nucleus has never been perceived yet during the actual process; it not unfrequently becomes visible afterwards.

The definition of the INDIVIDUALIZATION OF THE CELL-

CONTENTS *for the purpose of normal cell-formation is consequently this; that a nucleus is formed, and that this nucleus individualizes a portion of the contents by attraction.* The portions may be indeterminate or determinate. If the former, the quantity of contents isolated around the nucleus is uncertain. If the latter, either the whole contents or a definite fraction ($\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{5}$, $\frac{1}{6}$, $\frac{1}{7}$, $\frac{1}{8}$) becomes individualized around the nucleus, the denominator of the fraction giving the number of simultaneously individualized portions of contents.

CELL-FORMATION is the *individualization of a portion of contents, immediately followed by the formation of membrane.* The definition of cell-formation depends on the combination of the two constituent definitions. *Normal cell-formation,* therefore, in so far as it is endogenous, consists in this:—

A nucleus is formed in the contents of the parent-cell; this individualizes a portion of the contents by attraction, and this individualized portion becomes coated with a membrane by secretion over the whole of its surface.

But since, in animals, cell-formation also occurs outside cells, likewise commencing with a nucleus, and since in the *generatio spontanea* the first cells of plants or animals are formed either in external media or in other cells, in such a manner that these certainly cannot be regarded as parent-cells in the proper sense of this word, the definition of normal cell-formation must be brought into a more general expression.

In organic substances (which in animal cell-formation must contain proteine-compounds, in vegetable, azotized and unazotized compounds, such as albumen, gum and sugar) *a nucleus originates which, by attraction, individualizes a portion of the organic substances surrounding it; the individualized portion of organic substances becomes clothed by a membrane through secretion over its whole surface.*

In vegetable cell-formation the substance secreted as membrane is composed of ternary unazotized substances.

The homogeneous substance lying on the surface of the cell-contents and secreting the membrane, is mucilage (*schleim*) (albumen mixed with gum and sugar). Either the whole portion of contents individualized through the influence of the nucleus consists of mucilage, or of mucilage with which other matters are mingled; in the latter case, however, the extreme outer surface is always formed by mucilage. There are two especial properties of the mucilage which are of essential assistance in the formation of cells. The first is this, that whenever it becomes free or isolated, it acquires a perfectly smooth surface, on which the strongest magnifying power fails to discover the slightest prominences or depressions. A second property is, that where mucilage and other solid matters unite into a definite form, a portion of the mucilage always forms a superficial layer, the other substances being as it were repressed by it. The latter may be seen, both when the contents of a cell (especially of the cells of Algæ) flow out in water, and when through injury to the cell the contents become retracted from the walls, and divided into isolated portions. Through the homogeneous mucilage forming a continuous enveloping layer, or any portion of contents becoming individualized, this becomes at once a connected whole with definite boundaries. Through the mucilage possessing a perfectly smooth external surface, is produced a membrane, continuous and smooth, even at the very first moment of its formation.

Having become acquainted with the definition of cell-formation, and in it the conditions necessary to the process, we will now examine more closely some of its external relations. The cell may originate *in another cell* or *outside cells*. In the vegetable kingdom the law holds *that all normal vegetative cell-formation takes place solely inside cells; moreover, that all normal reproductive cell-formation, for the purpose of propagation, likewise occurs exclusively in the interior of cells.* Only the first cells of individuals originating through *generatio æquivoca*, are formed outside cells.

Schleiden was the first to express the formation of cells in cells as the universal law for vegetables. In many researches on the most diverse orders of the vegetable kingdom, and on the most varied organs of plants, I have never met with the formation of cells outside cells. Minute investigation in the proper stages of development always shows that the new cells proceed from parent-cells.

Meyen,* indeed, makes a portion of the cellular tissue of the young anther become dissolved, and new cells to originate in the homogeneous mucilage. But I have shown that Meyen mistook a very thin, delicate tissue for amorphous mucilage.†

Mirbel‡ considers that the cambium in the root of the Date-palm consists of an amorphous, homogeneous, thick fluid, in which the cells are formed. But in the roots of the Date-palm, as in all other cambium in entire sections, I find a continuous cellular tissue, and never any interruption by an amorphous mass.

Schleiden§ came to a similar result with regard to the cell-formation in cambium.

Endlicher and Unger‖ recently affirm cells to originate also through intercellular formation, appearing first as cavities in the intercellular substance, and acquire proper walls subsequently through the condensation of the latter. But if cells lie in a gelatinous mass, this is by no means a proof that they have originated in this. The history of development must decide whether the cells have been produced from the gelatinous mass, or the gelatine from the cells. My researches on the Algæ and Fungi show to me that, without exception, the cells exist first, and the gelatinous matter which subsequently surrounds them is produced by the cells. In the simple plants, such as *Nostoc*, *Palmella*, &c., the development may be traced from the very first cell. In the more complicated plants,

* Physiologie, Band iii, 119; pl. xii, fig. 2.
† Zur Entwickelungsgesch. des Pollens, p. 10, figs. 2-7, 31-36, 47, 48.
‡ Nouvelles notes sur le Cambium; Archiv de Muséum, tome i, pl. xxi.
§ Grundzüge d. wiss Bot. 1st Ed. vol. i, p. 109.
‖ Grundz. der Botanik, p. 33.

as, for instance, the Fucoideæ and Lichens, a thin-walled, parenchymatous cellular tissue exists at first, and the cells subsequently separate while gelatine makes its appearance between them. In many of the more complex Algæ and Florideæ I have been able to trace the development of the organs, step by step, from the first cell, and to bring this within definite laws of cell-formation. It thus becomes possible to determine in the perfect tissue, in which parent-cell each cell has originated. But it renders the hypothesis of an intercellular formation of cells wholly impossible.

Quite recently, Mettenius* has stated that the cells in the ovule and in the anthers of the Rhizocarpeæ, originate in an amorphous fluid, which is inclosed in a sac formed of a simple layer of cells. My own researches, however, do not agree with this description. I have many times seen a delicate-walled parenchyma during the cell-formation in these organs, and therefore am compelled to believe that the origin of the parent-cells of the pollen in the Rhizocarpeæ takes place in a similar way to that in the Phanerogamia. In a single organ, namely, in the antheridia of Mosses and Ferns, I am still in doubt regarding the cell-formation, not on account of anything unfavorable to the theory, but because generally nothing at all is seen. It is, besides, to be remarked, that the spermatic vesicles which are formed there are without doubt, utricles analogous to cell-nuclei (not to cells), and further, that on the other antheridia (of the Characeæ and Florideæ) no extra-cellular cell-formation takes place.

The law being established, that in plants both the vegetative and reproductive normal cell-formation takes place only *inside parent-cells, the relation of the cell-formation to these parent-cells* next demands consideration. The first question is, in what *number* and what *position* do these secondary-cells originate in the parent-cell.

The *number of secondary cells* is determinate or inde-

* Beiträge z. Kenntniss der Rhizocarpeen, p. 10 (1846).

terminate. In general, the rule may be stated, *that in vegetative cell-formation only two cells are formed from one parent-cell, in reproductive cell-formation, on the other hand, the number varies from one to an indefinite quantity,* and that here the smaller numbers (1, 2, 4, 6, 8) are constant, while the larger numbers (5 to 100, or more,) vary.

In the first place, as to *vegetative cell-formation,* from comprehensive researches in the Algæ, Fungi, Lichens, Florideæ, Mosses, Charas, in the vascular Cryptogamia and the Phanerogamia, I believe I am justified in venturing to express, as an universal law, *that here always two secondary cells originate in one parent-cell,* or, in other words, *that one cell divides into two.* Views and representations opposed to this I am compelled to regard as certainly incorrect.*

In *reproductive cell-formation,* the cells originate in various numbers in the parent-cell. *One* cell is found constantly in the formation of the germ-cell of the Zygnemaceæ, and several other Algæ and Fungi, also in the formation of spores and pollen-cells in the special parent-cells. Two, four, six, or eight cells are formed constantly in one cell in the formation of the germ-cells of several Algæ, many Fungi, of Lichens, also in the formation of the special-parent-cells of the Florideæ, Hepaticæ, Mosses, Ferns, and Lycopodiaceæ. The number varies from two and four to eight in the formation of the special-parent-cells of Phanerogamia. The secondary-cells originate in indefinite quantity in the formation of the germ-cells of many Algæ and Fungi, and in the formation of the endosperm-cells in the embryo-sac.

The *position* of the secondary cells in the interior of

* Thus Schleiden and Vogel figure three young cells in an epidermis-cell which has grown out into a hair. (Beiträge z. Entw. der Blutheuth. bei d. Legumin., Act. Acad. C. L. C. N. C. xix, 1, pl. x, fig. 38.) Schleiden also represents three secondary cells in a parent-cell from the terminal shoot. (Beitr. z. Anat. d. Cacteen; Mém. de l'Ac. Imp. des Sc. de St. Petersbourg, Sér. vi, t. iv, pl. viii, fig. 9.) In both the places named I have satisfied myself that only two cells are formed in a cell; that when, however, one of the latter quickly divides again, the appearance may readily be mistaken for three cells originating in one parent-cell. See pp. 119, 120.

the parent-cells is partly regular, partly irregular. The arrangement of the secondary cells is regulated by definite laws in vegetative cell-formation, and these produce a definite internal structure and external form of the organ, as I have pointed out in another essay,* in *Delesseria Hypoglossum*, and in the Mosses. In reproductive cell-formation we usually find a regular position connected with a definite number, an irregular arrangement with an indefinite number; when the germ-cells (in Fungi and Lichens) originate in the constant number of 2, 4, 6, or 8 in one parent-cell, they mostly lie in a row in the axis of the parent-cell, or else they exhibit a mode of arrangement having a definite relation to this axis. When the special parent-cells are formed in the constant number of four together, they are arranged tetrahedrally about the centre of the parent-cell. But when the cells originate in indefinite numbers (as in the formation of the germ-cells of many Algæ and Fungi, and of the endosperm-cells), there is nothing determinate in their relative positions in the parent-cell.

After the number and arrangement of the secondary cells within the parent-cells, comes the further question, in what way *do the particular parts of the parent-cell co-operate in cell-formation?* The *membrane*, as we have seen, in free and parietal cell-formation, bears no immediate share in the production of the new cell. It is merely the *contents* of the parent-cell which here come into consideration. Normal cell-formation may, in reference to the material relation of the parent-cell and secondary cell, be brought into the following categories:

1. *A secondary-cell originates in a parent-cell, entirely filling up the cavity of the latter*, and perhaps including the whole of its contents. Under this head are found the origin of the spore-cells in the special parent-cells of the four-spored Cryptogamia, namely the Florideæ, Hepaticæ, Mosses, Ferns, and Lycopodiaceæ, and of the pollen-

* Zeitsch. für wiss. Botanik. Schleiden und Nägeli. Part ii (1845).

cells in the special parent-cells of the Rhizocarpeæ and Phanerogamia. The special parent-cells contain a central nucleus. This disappears, and soon afterwards we find in the special-parent-cell a spore- or pollen-cell completely filling it, with a (primary) lateral nucleus. How this cell is formed, whether free in the contents, or around the whole contents, is still unknown.

2. *The central primary nucleus of the parent-cell divides into two secondary nuclei; the entire contents separate into two portions, each of which has one of these nuclei in its interior. The parent-cell divides by parietal cell-formation into two cells with central nuclei.* This process is met with in the formation of cellular tissue in the Algæ (and the Lichens?), and in the reproductive cell-formation of many one-celled or several-celled genera of Algæ.

3. *A central nucleus appears in the parent-cell, and divides into two secondary nuclei. The contents separate into two portions, each of which includes one of these two nuclei. The parent-cell divides, by parietal cell-formation, into two cells with lateral nuclei.* Here are to be enumerated the formation of cellular tissue of (most Fungi?) Florideæ, Hepaticæ, Mosses, Ferns, Lycopodiaceæ, Characeæ, Equisetaceæ, Rhizocarpeæ, and Phanerogamia. It is still uncertain whether the central, dividing nucleus is the primary nucleus of the parent-cell, becoming detached from the wall, and advancing into the centre,—or whether it is a newly-formed nucleus, originating in the centre, after the solution of the primary, lateral nucleus. The settlement of this question will at once decide, whether this cell-formation is actually different from that mentioned under 2, or is to be considered as merely a peculiar modification of it. With regard to the formation of the stomates of the Phanerogamia, I have expressed the opinion, that the primary nucleus of the epidermal cell becomes absorbed and that a new central nucleus is formed.* Mohl,† on the other hand, asserts of the same

* Linnæa, 1842, p. 238. † Vermischte Schriften, p. 258.

case, that the primary nucleus does not become dissolved, but that it is this which becomes divided.

4. *Four nuclei are produced, probably by the division of the primary central nucleus into two, each of which becomes again divided. The four nuclei assume a tetrahedral arrangement. The contents separate into four portions, each of which contains one of those nuclei in its centre. The parent-cell divides by parietal cell-formation into four tetrahedrally-arranged secondary cells.* I have hitherto only observed this process in the new single-celled genus of Algæ *Tetrachococcus.**

5. *The lateral (primary) nucleus of the parent-cell becomes absorbed. A new secondary nucleus makes its appearance in the centre of the parent-cell. At its sides originate two smaller nuclei.*

A. *The secondary nucleus of the parent-cell becomes absorbed. The contents separate into two portions, each of which contains one of those smaller nuclei in the middle. The parent-cell divides by parietal cell-formation into two cells with central nuclei. Each of the two nuclei divides into two nuclei, and each of the two cells divides again into two secondary cells by parietal cell-formation.*

B. *The two small nuclei divide, so that now four still smaller nuclei lie around the large secondary nucleus in the parent-cell.*

a. The secondary nucleus of the parent-cell becomes absorbed. The four small nuclei assume a tetrahedral arrangement. The contents separate into four portions, each having one of these four nuclei in the centre. The parent-cell divides by parietal cell-formation, into four tetrahedrally-arranged cells with central nuclei.

b. Some, or all of the four small nuclei divide, so that then from five to eight still smaller nuclei lie around the large central secondary nucleus of the parent-cell. The latter becomes absorbed. The contents separate into just as many portions as there have been small nuclei produced,

* Nägeli, Neuern Algensysteme." Zürich, 1847.

each containing one of them inclosed in its centre. The portions of contents are symmetrically arranged around the centre. The parent-cell divides by parietal cell-formation into from five to eight cells with the central nuclei.

The process described occurs only in the formation of the special parent-cells in the sporangium of the four-spored Cryptogamia, and in anthers. The modification given under A, I have observed in Florideæ, Mosses, and Phanerogamia; the modification B*a*, in Florideæ, Mosses, Ferns, Lycopodiaceæ, Rhizocarpeæ, and Phanerogamia; the modification B*b*, in Phanerogamia.

6. *In one parent-cell, or in two connected by conjugation, the whole of the contents unite into a globular or ellipsoidal mass, which is transformed into a free cell by the formation of a membrane on its surface.* Here refers the reproductive cell-formation of the Zygnemaceæ. Most probably, a central nucleus lies inside the contents, this, however, is in any case different from the primary nucleus of the one, or those of the pair of cells.

7. *New nuclei originate in a parent-cell, its primary nucleus becoming dissolved; each of these collects generally a very small portion of contents around it, which become coated by a membrane. The cells originate by free cell-formation in the contents of the parent-cell.* Here belong the formation of the germ-cells in some Algæ, in many Fungi, in the Lichens, and the formation of the endosperm-cells in the Phanerogamia.

8. *A cell grows out into a branch, and divides by parietal cell-formation into two cells, in such a way that one corresponds to the original cavity of the cell, the other to the expanded part.* Here are to be enumerated the formation of branches in Algæ, Fungi, Florideæ, &c. It exists probably in all plants, but may be recognised best in the organs composed of rows of cells. The origin of the cell-nuclei, and their participation in the cell-formation, is not yet certainly made out. It seems to me that the two following modifications exist, in respect to this:

A. The expanding cell possesses a central (primary)

nucleus before its growth begins, and retains it subsequently. A free nucleus also exists afterwards in the prolonged portion, and this probably originates spontaneously and independently of the primary nucleus of the original cell. *Each of the two secondary-cells possesses a central nucleus.* This branching cell-formation holds good for those plants in which the formation of cellular tissue follows the rule described under 2.

B. The expanding cell originally possesses a lateral (primary) nucleus. A second nucleus is subsequently found in the prolonged portion, probably originating spontaneously and independently of the primary nucleus. *Each of the two secondary-cells possesses a lateral nucleus.* This branching cell-formation occurs in such plants as have their cellular tissue formed according to the rule given under 3.

9. *A cell grows out into a branch. The whole of the contents of the branch* (if it be short), *or the terminal portion of its contents* (when the branch is long), *becomes isolated, and, by the formation of a membrane over its whole surface, is converted into a cell, which corresponds exactly to the cavity of the very short branch, or to the whole of the end of a longer branch.* In this way the germ-cells of several Algæ (e. g. *Vaucheria*) and Fungi are formed. The behaviour of the nucleus is not yet sufficiently known. The parent-cell possesses a lateral or central nucleus; the secondary cell likewise. The nucleus of the secondary cell probably originates in the branch, spontaneously and independently of the (primary) nucleus of the parent-cell. This mode of cell-formation is closely allied to that mentioned under 8. But there the division always occurs by means of a septum, which, as soon as it is thick enough, appears to be formed of two layers of equal thickness. From this condition of the wall we may conclude that two cells are simultaneously formed, dividing in the contents and cavity of the parent-cell. Here, on the other hand, only one lamella can be perceived in the curved septum, which

always has its convex surface directed toward the original cavity of the cell, and this lamella belongs to the cell formed in the branch. The cavity of the parent-cell at first appears to be closed in merely by the secondary-cell, subsequently it becomes closed in by its own piece of membrane. In this kind of cell-formation, therefore, as I believe, not two, but only one cell originates in the first instance.

VI.—THE GROWTH OF CELLS.

The cell is very varied in form at the moment of its origin. Cells produced by *free cell-formation* are always *globular* or *ellipsoidal*. Cells originating in numbers in a parent-cell, by *parietal cell-formation*, have *that form which is produced by the division of the parent-cell by straight or curved surfaces*. The variations of form under which these newly-formed cells appear are innumerable. The cell not unfrequently originates in a mathematically regular form, such as a sphere, ellipsoid, hemisphere, a quarter, segment, or section of a sphere, a cone, truncated cone, cylinder, semi-cylinder, a quarter, section, or segment of a cylinder, tetrahedron, cube, table, prismatic column, &c. &c.; but in most cases the form of the nascent cell is either intermediate between these mathematical figures, or exhibits all possible irregular figures, with plane (more rarely curved) surfaces. The faces and angles of the nascent cell are either all curved or all straight, or mixed. The number of faces by which the young cell is bounded varies, according to my investigations, from 1 to about 32, the number of plane angles from 0 to about 90, the number of solid angles from 0 to about 60.

From these facts it is evident how little the existing theory of cells is applicable, setting out from the spherical form, and deducing all the others from this as subsequent. In general I hold it as a rule that the cell retains the shape in which it originates. The shape is certainly altered in many cases; but taking a number as the test,

this is by no means the rule. When the cell does become altered in shape, it much more frequently happens that it passes from the polyhedral into the spherical, then from the spherical into the polyhedral form. This last, indeed, I believe only occurs in the endosperm-cells.

The growth of the cells is of two kinds. *Either the whole contents of the cell are simultaneously transformed, and the entire membrane expands at once*—I will call this *universal growth* (*allseitiges Wachsthum*), — *or new contents are continuously formed at one point of the surface of the cell, and with this new membrane*—I call this *apical growth* (*Spitzenwachsthum*).

In the growth of the cell it is necessary to distinguish between the growth of the contents and that of the membrane. The former appears always as causal and primary, the latter as caused and secondary. I shall here speak only of the growth of the membrane. This is a growth in thickness, and a growth in surface. The latter comes particularly into consideration in treating of the growth of the cell. It is conceived as an expansion resulting from the intussusception of organic molecules, and called a nutrition of the membrane. Without entering into any criticism of this theory, I will merely investigate, with what phenomena the growth of the membrane in surface is connected, in universal and apical growth of the cell.

When, in universal growth, the cell does not change its form, the membrane must expand uniformly in all parts. On the other hand, when the shape is altered, some parts of the membrane must expand more than others. The membrane consists of surfaces. In each of these faces the growth of the membrane must be decomposed into two factors, the expansion in the *two dimensions of a plane*. In each dimension we have three possibilities: either the expansion is $+x$, 0, or $-x$; either there is an expansion or none; or a diminution of the face of the membrane in this dimension. The last case, though rare, does occur in a few instances. The growth of the surface of a membrane, therefore, when the three possibilities in

each dimension are combined, exhibits, in general, nine possible cases, leaving out of the question that a multitude of differences in quantity may occur. In a cell where the growth is not uniform, we must distinguish at least between two faces; but cells occur with ten, twenty, and thirty faces. From this it may be conceived what an infinity of theoretically possible diversities exist for the universal growth of a cell-membrane in its totality, since this proceeds from the combination of so many and, more than this, such variable factors. I think, therefore, that in particular cases the growth of the membrane may be decomposed into its factors, but that it is impossible to establish general rules.

Schleiden* considers that the variations of form of cells result from unequal nutrition of the membrane, this taking place only in those places where one cell is in contact with another, or with a fluid;—moreover is more vigorous in those situations where a more considerable interchange of matters with other cells is going on, thus at the ends of elongated cells more strongly than at their lateral faces.†

Schleiden here starts from the facts, that the cells of the epidermis and of the septa in the air-canals are flattened; that in stellate and spongiform cells only the rays are in contact with other cells; that where a current of sap passes through a tissue, elongated cells are formed. The example cited, of *Caulerpa*, does not belong here, but to a growth of quite different kind, to *apical growth*.

The facts brought forward show the incontestible rule, if not absolute and unexceptional law; but I draw quite a different conclusion from them, namely, *that the cell-membrane grows least exactly where the greatest interchange of substances with external bodies takes place, and that it expands most where it is least occupied in receiving and giving off substances.*

I will first mention some negative reasons against

* Grundzüge d. wiss. Bot., 2d ed. i, p. 211.
† L. c. 250.

Schleiden's theory. If this were correct, we ought constantly to find the epidermal cell next the air *flat;* but there exist such as are not merely not flat, but of which the radial diameter is considerably greater than the tangental. Moreover, there ought to be a thorough distinction of form between epidermal cells in contact with water and those exposed to air, which is not the case. Again, the epidermal cells next the air should have a flattened outer surface, while in many cases they are elevated like papillæ. The cells of cellular plates (simple layers of cells) which exist in air, for instance the leaves of most Mosses, should be plane and flattened on both sides, which they often are not; while, on the contrary, cellular plates lying in water, e. g. Algæ and Florideæ not unfrequently have tolerably plane and flattened cells.

The positive reasons are more important than these negative objections. Assuming that a cell with equal diameters and cubical form becomes tabular, as may be the case in many cells of the epidermis and of the septa in the air-canals, the cell expands in two directions, which I will call the *tangental*, while it expands little or not at all in the *radial* direction; but the two faces to which the radial diameter is perpendicular, and which I will call *end-faces*, then expand, although in contact with air, not merely as much, but more than the other or *lateral faces*. If we assume that all three of the diameters of the cell were originally $= 1$, and such an increase to occur that both the tangental diameters become $= 3$, the radial diameter remaining $= 1$, we have the six faces, each of which originally possesses a square content $= 1$, now increased in such a way that the square content of the four *lateral faces* $= 3$, while the square content of each *end-face* has become $= 9$. In this case, therefore, the superficial square expansion of *a lateral face standing in contact with other cells is three times*, while that of *an end-face in contact with air is nine times* the original content. The latter is thus three times greater than the former. It may indeed be objected here, that the

expansion of the membrane depends solely on the nutrition of the lateral faces, a part of the latter having become end-face; but for this hypothesis we require a displacement of particular parts of the membrane, which has never yet been demonstrated in the cells of plants. Besides, I will show by another analogous example that such displacement really does not exist.

According to Schleiden, the elongated cells owe their shape to a current of sap, their ends being thus more nourished. On the other side it is to be objected, that if a cylindrical or prismatic cell is more nourished at its end than at its lateral faces, the cell will become proportionately broader not proportionately longer, since the ends determine the breadth of the cylinder or prism. But, according to the possibility mentioned in the previous example, a portion of the ends might continually become lateral faces; so that the ends would always remain the same size, while the lateral faces would grow by the addition of new portions of membrane, especially at both extremities (that is, near the two end faces). That this is not the case, however, is proved by such cylindrical or prismatic cells as have fixed points, on their lateral faces, from the conditions of which we may judge of the expansion of the membrane. The points of attachment of the branch cells are fixed points of this kind, in plants and organs of very simple structure. In Confervaceæ and Callithamniaceæ the branches often originate at a very early period; they are attached to the upper ends of the cylindrical lateral faces. Now, I observed in several cases *that the superficial contents of the lateral faces expanded ten to twenty times more than the end faces, after the origin of the branch, and that during this the branch always either remained near the end, or was but slightly removed from it.* The lateral face is free, and in contact with water; the end is in contact with a cell. According to Schleiden's theory, the end face ought to be more nourished than the lateral, since it effects the exchange of organic substances, while the latter only serves for the absorption of inorganic

nutriment. But just the reverse occurs here, and it is actually the lateral face which expands. The assumption that the lateral face is at all enlarged by portions of the end face being pushed over to the side is impossible here, since this must necessarily remove the branch-cell gradually away from the end. That the branch-cell is not all moveable on the lateral face, and that its situation may be regarded as a safe criterion here, is proved by the pore which the branch-cells of the Callithamniaceæ possess in the centre of their basal surface, and which certainly is not moveable. The same may be observed in Ceramiaceæ and in other Floridæ; as, for instance, in *Polysiphonia*, where the prismatic central cell frequently bears a branch.

The objection that the plants mentioned live in water, does not appear to me an important objection. For it can certainly at most be asserted, that membranes in contact with water will be more readily nourished than those exposed to the air; but not that membranes which are moistened with water, possess a more active nutrition than such as are applied against other cells. Besides which, that objection will, in any case, not apply to *Polysiphonia*, where the elongated central cells, the growth of which furnishes the same result, are wholly surrounded by cells. In order further to settle that doubt, I may add that cylindrical cells, the lateral faces of which are exposed to the air and the ends applied to cells, also, as for instance in several filamentous Fungi and many hairs of Phanerogamia, exhibit a similar condition to that of the cells forming the joints of the Callithamniaceæ; *that, namely, their lateral faces expand considerably more than their end faces*, which here alone officiate in the reception and transmission of fluid nutriment. The growth of the cell may be judged of here again by the relative position of the branch-cell, and in addition by the relative position of the nucleus of the cell. Hairs consisting of a single cell, are originally little hemispherical or conical cells; the parietal nucleus lies at some point of

their periphery. The cell often becomes twenty to forty times longer than it was at first. The cell is exposed by all its surface, except the base, to the air; it acquires its fluid nutriment solely through the basilar surface. If the membrane were principally nourished by the passage of nutrient matter through it, the basilar surface alone would be much expanded. Now, since the nucleus exists in the earliest condition, and since normally it is not moveable on account of its lateral attachment, it must, if the theory were correct, lie normally near the apex of the enlarged cylindrical cell, from the growth of the membrane at the base. But it lies, without distinction, sometimes at the apex, sometimes in the middle, and sometimes at the base of the cell.

Observations on elongated cells, or vessels with spiral, annular, or porous lignification, afford me similar results. If such cells or vessels grow after the lignification has become evident, the spiral fibres, the rings, or pores, separate uniformly on the whole of the lateral surfaces; the best proof *that such elongated cells or vessels expand at their lateral faces, and not at their terminal faces, where the current of sap passes through the membrane.*

The question still remains of the behaviour of the stellate or spongiform cells. They are at first parenchymatous, but by the secretion of air become separated from each other in the greatest part of the surface, remaining united together only in places. At the points of contact the cells elongate radially. Schleiden calls this a "growing-out" (*Auswachsen*). I see nothing in it but a mechanical drawing-out of those places which cannot separate from the other cells, through the air which has been excreted. The growth of the cells is a different and much more independent process, while the radiating elongation of the stellate and spongiform cells stands in direct relation to the quantity of air secreted. The undulated and dentate epidermal cells, however, which are *dove-tailed* into one another, and which Schleiden also cites, prove in any case nothing for his

theory, because a membranous surface, which is uniformly bounded at all points by another surface of membrane, must exhibit like behaviour at all points in reference to nutrition and expansion.

From the facts here brought forward, I deduce the conclusion, *that the cell-membrane normally expands less in those places where it serves for the reception and emission of the nutrient matters, or where it officiates in an interchange of substances or a current of sap; that, on the other hand, it normally expands more at those places where it has little or no nutrient matter to manage.*

The *apical growth* is altogether different from the universal growth of cell-membrane. In an earlier memoir on *Caulerpa*,* I have pointed out this apical growth, and discussed its characters at length.† The apical growths may be observed most easily in the filiform, branched, single-celled Algæ and Fungi, as in *Caulerpa*, *Bryopsis*, *Achlya*, &c. The lower part of the cell is quite perfect; little or no change occurs in the contents; the cavity is filled with clear, colourless fluid, and on the wall lies the mucilaginous layer, with the chlorophyll- and starch-globules: the membrane expands little or no more. Toward the extremity the membrane becomes thinner; it is there that new contents and new membrane are formed.

Immediately below the growing point lies a layer or small disc of homogeneous mucilage. Below, this passes into granular mucilage. To this follows a mass of granular mucilage, in which originate starch, chlorophyll, or other colouring matters. Still lower down, the solid contents are deposited upon the walls.

* Schleiden und Nägeli, Zeitschr. f. wiss. Bot., Heft i, p. 134.

† Schleiden (Grundz. d. w. Bot. 2d ed. i, p. 212) confounds the apical growth with the unilateral expansion of universal growth. It is by no means clear to me how he imagines *Caulerpa* to be "a body which at least *appears* like a single cell;" further, how "the most decisive proof" of anything can be deduced from this *appearance*. That *Caulerpa* actually *is* a single cell, follows, in my opinion, both from the researches I have published and from its relationship to *Bryopsis*, *Valonia*, *Codium*, *Halymeda*, *Udotea*, *Vaucheria*, &c.

In the disc of homogeneous mucilage lying in the *punctum vegetationis*, new homogeneous mucilage is unceasingly produced, so that it remains the same, although its lower edge is continually being converted into granules, and thus a portion unceasingly given over into the zone of granular mucilage. The lower part of the latter passes continually over to the coloured zone, since in it the formation of colouring matters, starch-granules, &c., begins. The lower part of this continually applies itself to the wall. In this manner the relations of the particular zones remain the same, although an unceasing process of transformation is going on in them.

The apical growth is thus connected with a production of contents, which takes place at the apex of the cellular branch.

The membrane, which is of tolerably uniform thickness in the lower part, becomes gradually thinner toward the end of the cellular branch. Immediately over the disc of homogeneous mucilage at the *punctum vegetationis*, the membrane is very delicate, as in a young newly-formed cell. It always remains so during the growth of the branch. The gelatinous matter secreted by the disc of mucilage is never appropriated to the thickening of the membrane, but solely produces the expansion of it necessitated by the growth of the apex. The membrane expands likewise beneath the apex, and exhibits phenomena there, similar to the *universal* growth of the cell without *apical* growth; at the same time it becomes thickened by deposition of new layers.

The membrane therefore exhibits different behaviour at the apex and beneath this part. At the apex it is continuously nourished, so to speak, or, as seems to me a more correct expression of the fact, new membrane is incessantly produced; the process of formation of membrane going on there remains the same so long as the apical growth lasts—in unlimited axes, therefore, it is unlimited also. Beneath the apex, the membrane grows

by universal expansion and thickening up to a certain point; the process of formation of membrane then gradually changes, and at length ceases.

The behaviour of the membrane at the apices of growing axes, and below these apices, exhibits exactly the same opposed relation, as the formation of membrane in cell-formation, and the universal growth of membrane after cell-formation.

The apical growth, therefore, consists not merely of a continuous production of contents, but also of a continuous production of new membrane at the apex of the axis.

Many cells with apical growth branch. They develope new branch-cells from their lateral surface, and these elongate by a repetition of the apical growth. Cells, also, which do not grow at the apex themselves, may send out a branch which exhibits apical growth; thus the cells which *grow out* into an appendage, as in the cells constituting the articulations of the Confervas, to form a branch-cell or a root; many cells of young bark or epidermis, to produce a hair or radical fibril; the sporangial cells of *Achlya*, to discharge the motile cellules (pl. III, figs. 4, 6, 8), &c.

The phenomena occurring in these cases, when they can be perfectly seen, as is possible, for instance, in *Bryopsis*, are as follows:—At some point on the surface of the cell, where the branch is to be formed, a little disc of homogeneous mucilage is produced immediately beneath the membrane; the mucilaginous layer here produces a definite quantity of new mucilage. Then the cell-wall becomes elevated into a little triangular, hemispherical, or conical papilla, filled with homogeneous mucilage. The papilla grows larger. The mucilage becomes granular at the lower part. The granulation of the mucilage advances continually upwards. The formation of chlorophyll, or other colouring matter, and of starch, commences at the base, and also progresses upwards. Then the mucilage at the lower end begins to apply itself upon the walls,

and the cavity is filled with colourless fluid, and comes into communication with the transparent cavity of the original cell.

The apical growth consequently commences with the new formation of homogeneous mucilage, which produces new membrane, and is continued by the persistence in new formation of membrane-forming mucilage.

The question now comes, what is the relation of the apical growth to universal growth and to cell-formation? The relation may be conceived in two ways: 1st, in reference to the contents; 2dly, in reference to the membrane. I will here, as in the universal growth, only enter upon the latter point.

Schleiden and Schwann have strictly discriminated two epochs in the development of the cell, namely, the origin of the membrane, and its growth. This distinction, however, according to the view of cell-formation above established, is certainly not so great as it appears in Schleiden's and in Schwann's theory. According to this theory, the material for the original production of the membrane is merely furnished by the mother-liquor, from which it crystallizes; the material for the growth of the membrane is, on the contrary, partly or wholly furnished by the cell-contents; it is, namely, deposited from the contents, or acquired by the endosmose and exosmose through the membrane.

According to my theory of cell-formation, the original production and the growth of the membrane have the same material cause. For both purposes, organic matter (in plants mostly gelatine) is secreted from the contents. Origin and growth are, in the same way, a product of the contents. They merely differ from each other relatively. The original production of membrane gradually changes into growth of membrane. A line of demarcation between them is quite arbitrary.

We see, therefore, that in this point the membrane behaves just like every other organism. In none, certainly, does there exist a strict and absolute boundary

between origin and growth. But if these two ideas are not absolutely different from each other, we shall still let them stand side by side as separate, in their relative difference.

When a cell is produced, a portion of organic matter becomes individualized and inclosed by a membrane, through secretion of organic substance. *With* CELL-FORMATION, *therefore, is connected an individualization of organic matter and a formation of new membrane.* When apical growth begins at a point of the surface of a cell, and a branch-cell is formed, a portion of homogeneous mucilage appears, which secretes membrane from within outward. *With the commencement of* APICAL GROWTH, *therefore, is connected the individualization of a portion of the contents and a formation of new membrane,* and, with the *continuous* APICAL GROWTH, *a continuous formation of new membrane.* I will consider these two points a little more minutely.

When secondary cells originate in a parent-cell, definite portions of the contents are repeated in such a manner, that from that time they possess an individual existence, having been up to that period undistinguished parts of the parent individual. When a branch is produced upon a cell, a definite portion of the contents is likewise separated, and indeed a small portion of the mucilaginous layer. This has from that time an individual vitality wholly distinct from all the rest of the contents. This little portion of mucilage is the rudiment from which a new branch is produced. The branch of the *ramified cell,* however, has quite the same import as the branch of a *many-celled plant.* In the ramified cell, as in the many-celled plant, it may, under certain circumstances, be detached and become an independent, new, and individual plant.

With the commencement of the APICAL GROWTH *in the formation of a branch, consequently, is connected the individualization or separation of a portion of the contents, as well as with cell-formation.*

These secondary cells originate in a parent-cell; the

cell-membranes are produced around the individualized portion by a new process of formation; the contents secreting organic matter around. When a cell-branch is produced, the individualized portion of contents forms membrane only on its outer face. The growing out of the cell-wall into a branch, however, does not, as I believe, happen through unilateral nutrition, but by a new formation, especially from the fact that the wall of the parent-cell or parent-branch is sometimes already tolerably thick and lamellated before the branch is formed, and because the growing out then assumes an aspect much more as if the membrane of the parent-cell were pushed outward and broken through, than as if it were expanded and formed a branch through nutrition. The origin of a cell-branch is distinguished from the origin of a cell by the fact, that in the former membrane is formed only on one side, in the latter over the whole surface; and that in the former the production of membrane is continued, in the latter exists but at one short period. *The* APICAL GROWTH, *therefore, like* CELL-FORMATION, *is connected with a formation of new membrane, but this is unilateral and continuous.*

In cell-formation, as soon as the membrane is formed, it expands by universal growth. In apical growth, as the new membrane is every moment produced, it also at once begins to expand by universal growth. In both cases a thickening of the membrane is combined, at the same time, with the expansion. In both cases, moreover, the expansion only persists for a time, and then ceases. Finally, in both cases, the expansion of the membrane is at all points equal or unequal; in uniform universal growth, the cell or cell-branch is not altered in form; in irregular universal growth, the cell or cell-branch assumes a shape different from that it originally possesses. As in cell-formation, so also in apical growth, the new formation of membrane and its growth, are only relatively different from each other. Both are conditioned by the secretion

of organic matters from the contents; one passes into the other without any definite boundary.

In reference to the *formation of membrane*, therefore, we may establish the following distinctions: *In* CELL-FORMATION, *an universal and momentary production of new membrane takes place.* *In* APICAL GROWTH, *an unilateral and continuous formation of new membrane appears.* *In* UNIVERSAL GROWTH, *which follows both cell-formation and apical growth, an expansion and thickening of the newly-formed membrane takes place.*

The apical growth may *begin* in a cell in two ways, in reference to its relations to the life of the cell in time and space. In the first case, the apical growth begins at once with the formation of the cell. *A portion of the contents becomes individualized, and secretes membrane over its whole surface,* whereby the cell is formed; *this new formation of membrane continues at one point of the surface, and the cell goes on growing in this direction.* The apical growth is here immediately connected with the cell-formation. It begins directly after the origin of the cell, before the universal growth has commenced.

In the second case, on the contrary, the cell first expands by universal growth. The membrane becomes thickened; the contents are applied upon the internal surface. *Then a portion of homogeneous mucilage is formed at one point of the surface, beneath the membrane, and with this begins a new apical growth,* as I have above described it. The apical growth, therefore, does not here follow immediately the cell-formation, but the universal growth of the cell. It may occur, either in a cell without apical growth, or in a cell with this, as on the lateral part of a cell-branch growing at the apex, and always appears as a *growing-out of a point of the surface.*

Through the first kind of apical growth the nascent cell grows longitudinally. By the second kind the cell branches.

The apical growth is also variable in its *duration.* *It*

is LIMITED *or* UNLIMITED, *according as it either ceases at a definite time, or continues as long as the plant lives.* Apical growth is limited in all cells, growing at the apex, of many-celled plants, also in many axes of unicellular plants. It is unlimited in particular axes of unicellular plants, as, for instance, in the main axis of *Caulerpa, Bryopsis,* &c.

Apical growth is not found in all cells; it is wanting even in the great majority of cells. I have observed it in unicellular Algæ, as *Caulerpa, Bryopsis, Vaucheria, Valonia, Codium, Halymeda, Udotea;* in unicellular Fungi, as *Achlya, Bremia, Mucor,* &c.; in the terminal cells of many Algæ, Florideæ, and Fungi, as, for instance, *Conferva, Dasycladus, Griffithsia, Polyactis,* &c.; in the roots of many Algæ, Florideæ, and Fungi; in unicellular hairs, or the terminal cells of many-celled hairs, in the pollen-tube; lastly, in all cells growing out into a branch, as, for instance, in the cells forming the articulations of many Algæ, Florideæ, Fungi, and the organs consisting of series of cells in the higher plants, moreover in the epidermal cells of the higher and lower plants, &c.

ON

THE UTRICULAR STRUCTURES

IN THE

CONTENTS OF CELLS.

BY CARL NÄGELI.

TRANSLATED FROM

SCHLEIDEN U. NÄGELI'S ZEITSCHRIFT F. WISS. BOTANIK, 1846.

BY ARTHUR HENFREY, F.L.S.

UTRICULAR STRUCTURES.

It is now some years since I first imagined that the phenomena exhibited by various bodies occurring in the cell-contents, and supposed to be solid, could only be explained by the hypothesis that they were utricles, having an inclosing membrane with inclosed contents. The minute size of the objects in question, the uncertainty which attributes to the appearances, on account of the different refractive power of different substances, and the circumstance that, already, repeated attempts to demonstrate cellular or utricular structures in the cell-contents had failed, impressed the necessity of great circumspection. I now lay before the physiological public my researches on the various forms of the contents in the various kinds of cells, only after extensive observations, and a confirmation of them by a comprehensive critical inquiry.

Earlier and more recent theories, which declare the cells to originate from starch- or chlorophyll-granules, and from which might be deduced a cellular structure of these granules, may conveniently be passed over as unfounded.

Earlier authors, likewise, who use granule and utricle as synonymous terms, and imply no distinction between the two expressions, merit no special mention.

More recently, granules and utricles have been placed in opposition to each other. The first are considered to be solid, the latter hollow. After this definition, the opinion that cells inclose only granules gradually gained the upper hand. Better instruments and more

accurate methods of investigation showed that what had been considered hollow, was really solid.

It was further attempted to show, in some granules, that their mode of origin was analogous to that of crystals and different from that of cells. They were supposed to be produced by a nucleus, through the deposition of layers on the outer surface.

Particular theorists persisted in the view that the formations in the contents were utricles, the analogy to a cell floating in their minds. The empirical proof that such an agreement existed was not given.

In the present condition of the researches, therefore, the questions are: *whether the so-called granules exhibit analogy with the crystal or the cell; whether they are solid or hollow; whether they are formed by the deposition of layers around a nucleus or in some other way?*

The first question is to be solved by the decision of the last two. The second is, of course, to be answered with the statement, that as a rule the so-called granules appear *solid*. But this does not establish anything in regard to their nature, since utricles may become or appear solid in various ways, while granules may at the same time be hollow. The answer to the third question alone possesses scientific interest, since it decides incontestably as to the crystal-like or cell-like nature.

Thus the entire question turns upon this: *Do the structures in the cell-contents originate by stratified deposition from without, and do they fulfil a vital process corresponding to this crystal-like mode of formation?* or, on the other side: *Do they originate in a similar manner to the cell; do they consist, like this, of a membrane and contents inclosed by this membrane; and do they exhibit, in general, in reference to the contents and membrane, analogous alterations during their life, to those we are acquainted with in the cells?*

Some time ago I pointed out two utricular structures in the contents of cells, the nuclear utricle,* and peculiar

* Schleiden und Nägeli, Zeits. f. wiss. Bot., i, p. 68; Ray Trans., 1845, p. 246.

utricles producing starch and chlorophyll, in *Caulerpa*.* As a criterion of their utricular nature, I mentioned that they do not originate by deposition on the outside, that they inclose, in a complete membrane, contents distinct from this membrane, fluid, semifluid, or, sometimes, partially granular, that they grow by expansion of their membrane, and transform their contents, and that they propagate in the same way as cells.

In their essential peculiarities, therefore, these utricles present the character of cells; and we shall consequently, in the decision whether anything is an utricle or not, take especially into account the phenomena which are analogous to the phenomena of cell-life. On the other hand, we shall not determine whether anything is to be considered as an utricle by the circumstance of its being hollow or solid. Now, as cells occur which appear solid, either because their very delicate membrane is quite filled with contents, or because they are completely lignified, so also do such utricles present themselves. Moreover, hollow structures occur in the cell-contents which are not utricles.

I must enter more minutely into the latter point, because it has very often led to error. Homogeneous mucilaginous contents frequently exhibit transparent, colourless cavities. These are globular when they are isolated, or at least are not very near together; they become parenchymatous when they are closely crowded. They vary much in size; sometimes a great number find place in one cell, sometimes one, two, or three, occupy almost the entire cavity.

The mucilage in which these cavities appear is either of equal density throughout, or it is denser at the periphery of the cavities, and forms as it were a membrane around them. In such cases the cavities appear like utricles. This utricular structure is the more deceptive the more the density of the mucilage immediately on the surface of the cavity differs from that of the rest of the interior of the cell; it is still more deceptive when these

* Loc. cit. p. 149.

cavities are larger and exist in smaller numbers, and when the mucilage *generally* is more diluted and transparent. The cavities have, on the contrary, more the aspect of real, mere cavities, when they are small and numerous, and when the mucilage is dense and opaque.

These cavities contain water. They are seen in most cells which are passing from the condition in which the cavity is wholly filled with homogeneous mucilage, to that in which the mucilage is deposited upon the wall as a mucilaginous layer. They also occur, not unfrequently, at a subsequent period, when the cells contain a homogeneous mucilage besides the solid matters; I have seen them in this late stage of the life of the cell, from the cells of *Confervæ*, *Siphoneæ*, and Hyphomycetes, upwards to the parenchyma-cells of the Phanerogamia. They are here a normal phenomenon of cell-life.

The following is the probable mode of origin of these cavities. Larger or smaller quantities of water separate from the mucilage, and from physical laws acquire a globular form. From the loss of water, the mucilage contracts and becomes more dense. If the drops of water lie long unaltered in the mucilage, the layer of the latter in contact with the water coagulates through its influence, as is always more or less the case with mucilage or albumen in water. In this way originate in the cell-contents the colourless pseudo-utricles possessing a special membrane. In conformity with their origin we never see any other contents but colourless fluid in them, and never observe any alteration in their apparent membrane.

That this explanation of the normally occurring utricular cavities is correct, is proved by the abnormal formation of similar cavities, either when mucilage or albumen is mixed with water, or when we allow water to act endosmotically upon a cell containing homogeneous mucilage. In both cases, similar globular, colourless, sharply-defined cavities are frequently produced, the mucilage at the same time contracting and becoming more dense and opaque.

These cavities in the mucilage must by no means be

called utricles, because the utricles, according to their definition, are to be described neither as hollow spaces, nor as hollow spaces surrounded by a membrane. They must at least possess *a special membrane and contents subject to special metamorphoses.*

1. *Nuclear Utricles, Nuclei.*

That the nuclei are utricles I have pointed out in another place.* I then brought forward the following reasons in favour of this opinion:

1. When the nucleus admits of minute examination, in respect of size and density, a membrane, and contents distinct from this, may always be recognised. The membrane is only overlooked where the nuclei are too small, or where dense contents are inclosed in a delicate membrane. In the latter case, it is sometimes possible to render the membrane visible by the action of re-agents.

2. The membrane is different from the contents (by no means the outermost layer of them); it is not coloured by iodine and is composed of gelatine, while the contents are usually coloured brown by iodine and consist of mucilage.

3. The contents exhibit peculiar transformations, which are analogous to those of the cell-contents.

4. The membrane is proper to the nucleus (by no means a mere deposit from the cell-contents), as is proved by the *propagation* of the nuclei, which exhibits the same phenomena as the propagation of the cells.

I may add here that the membrane of the nucleus may sometimes be recognised very distinctly, when it becomes expanded through endosmose of water.†

Schleiden‡ thinks "that the nuclei become hollow

* Schleiden und Nägeli, Zeitsch. f. wiss. Bot., i, p. 68; Ray Trans. 1845, p. 246.

† See p. 110 of this volume, pl. ii, fig. 9, *i*, *k*, *l*, *m*.

‡ Grundzüge, second edition, i, p. 199. Schleiden reproaches me for an unsettled terminology. I have called the nucleus an *utricle* (*bläschen*), and

afterwards, since there is no trace of a membrane in the young free cytoblasts, and the origin of these even appears to contradict my view."—If the origin of the nuclei could be observed, this would afford the most decisive proof of one or other of the theories. Schleiden indeed describes the origin of the nucleus as a confluence or conglomeration of mucilage-granules and nucleolar-globules. I cannot agree at all in this opinion. The commencement of the formation of the nucleus may be quite definitely distinguished, while it is yet little larger than the globules of mucilage, and may be traced onwards uninterruptedly, any deposition of mucilaginous granules upon it being out of the question. On this point I refer to the preceding treatise, where it treats of free cell-formation in the embryo-sac.* The origin of the nuclei free in the cell-contents consequently affords no evidence in favour of the assumption, that they are solid granules without a membrane.

Schleiden says moreover, that "in young free cytoblasts no trace of a membrane is found." The youngest nuclei consist of a homogeneous substance. They are either more dense than the surrounding fluid, or, as is frequently the case in young parenchyma-cells, they are less dense than the surrounding mucilaginous contents, and appear like hollow spaces in it. In this youngest condition examination certainly reveals no membrane distinguishable from the contents; but this is not a circumstance which can be of weight in judgment of the nature of the nucleus. If optical instruments never become improved

used *nuclear utricle* (*kern-bläschen*), as synonymous with *nucleus*. I still know of no better terminology to substitute for it. On the one side, the analogy with the other kinds of utricle requires the name "nuclear utricle;" on the other hand, custom of language, brevity of expression, and the contrast with nucleolus, leads to the use of the term "nucleus." The confusion of language is always greatest when conceptions are in process of discrimination. Selecting from a hundred examples in botany, does not the same author use spiral vessel and spiral-fibrous cell, or liber-fibre and liber-cell as synonymous, although in regard to the last example, the word fibre already represents a perfectly definite conception.

* See page 103 of this volume.

so far as to enable us to distinguish the organic molecules, there will always be still entire stages, in the development of membranes, in which it will be impossible to distinguish them from the homogeneous contents lying close to them, and refracting light in a similar manner, and in which their presence or absence must be decided on upon other grounds.

The matter stands in a similar position in regard to cells. The relation of contents and membrane is evident in fully-formed cells, and it may be carried back by a conclusion from analogy to the young cells. The young cells in the embryo-sac, if they possess homogeneous and not granular contents, often do not allow of our perceiving the membrane for a long time. Free germ-cells (spores) of Algæ, Fungi, and Lichens, mostly attain a considerable size (at least as considerable as that of the nucleus mentioned by Schleiden), without the possibility of seeing the least sign of membrane, and yet they are young cells, to which no one will deny a membrane.* Moreover, cells occur also, about the size of young nuclei, on which no membrane is visible in their lifetime. Among these are some species of *Protococcus*, of *Palmella*, and of other Palmelleæ.

If, then, it is impossible to distinguish the membrane from the contents in *young* free cells, or in *small* free cells generally, on the other hand the membrane is usually visible in parietal cells at the moment when the cell originates, and in those very places where the apposition of the secondary cells forms a septum. The same occurs in nuclei which originate by the division of a parent-nucleus. Here, too, as in the division of cells, a septum is visible, formed by the two meeting membranes.†

The comparison of those free cells is especially necessary here, in which membrane and contents cannot be clearly distinguished even in the fully-developed con-

* See pages 95-6 of this volume.

† Nägeli on Cells, Part I, Ray Transl. 1845, pp. 231, 246.

dition. In them the septum is visible, as a line, only in the moment of the division. If, therefore, analogy with other cells does not afford evidence of the presence of a membrane to these cells, we can only draw conclusions in respect to it from the septum which is seen in the propagation; but when we can succeed in bringing two such free cells together, in such a manner that, where in contact, they are reciprocally somewhat flattened against each other, the two membranes become visible at once, as a septum, while at the remainder of the periphery, as before the union was the case at all points, nothing can be seen of the membrane. I have accomplished this in *Palmella, Protococcus,* and *Saccharomyces.*

Nucleus and cell then exhibit, in reference to their membrane and its relation to the contents, the same phenomena. In small and young free individuals, the membrane and contents are not distinguishable at first sight; they do not become so until they have undergone further development. In individuals, however, which originate through parietal formation, the membrane is evident as a septum in the earliest condition. The sole distinction, following from the nature of the case, which prevails between nucleus and cell is, that there are far more conditions of the nucleus than of the cell, in which a distinction between membrane and contents is impossible, since the phenomena are represented on a considerably smaller scale in the nucleus than in the cell.

After disposing of the objections above mooted, I proceed to a short exposition of the vital phenomena of the nuclear utricle.

The nucleus originates in two ways: either free in the contents of a cell, or by the division of a parent-nucleus. If the nucleus originates by division, the phenomena presented are similar to those in the division of a cell. A septum becomes visible in the parent nuclear utricle, dividing it into two halves (as in *Tradescantia*);* some-

* Nägeli on Cell-Formation. Ray Trans., 1845, p. 184, pl. vii, fig. 20.

times a nucleolus is visible in both halves (as in *Anthoceros*).* Since the division of the nucleus exhibits exactly similar phenomena to the division of cells, I conjecture that a *parietal formation of the nuclear utricle* must be assumed in the former case like the *parietal cell-formation*† in the latter.

The process just described may perhaps be borne out by the facts known regarding the division of the nucleus in animal-cells.‡ A large nucleolus appears in the parent-nucleus, and divides; the two secondary nucleoli retreat from each other, and the nuclear utricle divides into two secondary nuclear utricles, in such a manner that each of them incloses a nucleolus.

If we may draw conclusions as to the division of the nucleus from the division of cells, where the appearances are the same, the parietal formation of the nuclear utricle depends on the following events: *Two nucleoli appear in the parent nuclear utricle; the contents of this separate into two portions, each of which incloses a nucleolus, and becomes clothed by a membrane; the membrane of each of the new nuclear utricles is in contact partly with the wall of the parent-utricle, and partly with that of its fellow, whereby a septum is produced in the parent-utricle.*

When the nuclei originate free in the cell-contents, the circumstances are probably the same as those occurring in the formation of free cells. It appears, namely, that, *first, a nucleolus is formed; that a layer of mucilage is deposited around this, and that the membrane of the nuclear utricle is produced upon the surface of the mucilage.* At least the phenomena which can be observed in the formation of free nuclei allow of this explanation, which is rendered probable by the analogy to free-cell formation. I refer the reader, on this point, to the article "*Free cell-formation*" in the preceding essay.§

* Loc. cit. pl. vi, fig. 38.
† Loc. cit. p. 284.
‡ Kölliker, Entwick. der Cephalopod., pl. vi, fig. 68.
§ Page 95 et seq.

When the nucleus originates free, it is in its earliest condition globular; when it originates with a fellow-nucleus in a parent-nucleus, it is originally hemispherical, but then, separating from its fellow, it rapidly assumes a globular shape.* The nucleus retains its spherical shape if central in its cell; it only becomes ellipsoidal when about to propagate; but if the nucleus occupies a lateral position in its cell, it becomes flattened on one side. Seen in front, it then appears circular or ellipsoidal, while laterally it seems more or less compressed.

The growth of the nucleus is sometimes very slight; sometimes an expansion of from twice to ten times its diameter takes place.

The membrane of the nucleus never acquires any considerable thickness, and never exhibits lamellation or lignification as in cells.

Young nuclei, as well when they have originated free as by division, generally possess homogeneous, colourless mucilaginous contents. These may be dense and opaque, or almost transparent. Subsequently they become granular, and we may then distinguish a transparent fluid, mucilage-granules, starch-granules, chlorophyll-granules, and drops of oil. Sometimes the homogeneous and granular mucilage becomes deposited in the form of a layer on the inner surface of the membrane, so that the rest of the cavity is filled merely with watery fluid. Sometimes the nucleus contains amorphous colouring matter, so that it appears homogeneously red† or green.‡ Amorphous chlorophyll may also clothe the inner surface of the membrane, merely in patches.§ For more minute particulars, I refer to my earlier essay on this subject.‖

There are generally from one to three nucleoli in the contents of the nucleus; sometimes their number rises to five and six. These nucleoli appear to be rarely absent. Probably they are always present, and merely invisible

* Nägeli on Cell-Formation; Ray Trans., 1845, p. 184, pl. vii, fig. 20.
† Loc. cit., 1845, pl. vi, fig. 26. ‡ Loc. cit. pl. vi, figs. 36-40.
§ Loc. cit. pl. vi, fig. 41. ‖ Loc. cit. p. 219 et seq.

on account of the minute size, or the opacity of the nucleus. It is, moreover, probable, when at a later period several nucleoli are met with in one nucleus, that one alone existed in the first instance, and that the rest have originated subsequently. I have already expressed my opinion on this point in the section on "*Free cell-formation*" of the preceding essay.*

The nuclei terminate their existence either by solution, in consequence of weakness resulting from age, or by propagation. The mode in which nuclei propagate, has already been described when treating of their origin.

2. *Spermatic Utricles.*

The spermatic utricles are those in which the spermatic filaments originate. Hitherto they have been called cells or cellules. I formerly thought that they might have the import of nuclear utricles, because always one such utricle appeared in a cell in the antheridia of the Characeæ, and because a nucleolus always existed previously in each utricle.

Without intending now to deny this analogy, I believe that the spermatic utricles are not perfectly identical with the nuclear utricles; in the first place, because the production of the spermatic filament is a characteristic of which the nuclei are wholly devoid, and further, because in animals, and probably also in plants,† several such utricles are sometimes formed in one cell.

It is no proof of the spermatic utricles being cells, that in the Florideæ, Mosses, and Ferns, they are applied closely together so as to form an apparent tissue; since it is quite as possible as not, that they are produced in one large cell resembling an embryo-sac, or that the cells in which they are formed become dissolved.

* Page 107.

† Nägeli on the Propagation of the Rhizocarpeæ; Zeitschr. für wiss. Botanik, H. 3, p. 188 (1846).

The mode of origin of the spermatic cellules is unknown, as also of the propagation.

The shape of the spermatic utricles is globular or ellipsoidal when they are free—parenchymatous when they are closely packed together.

The contents are originally homogeneous and mucilaginous. In this may be perceived globular utricles or solid corpuscles, probably analogues of the nucleoli of the nuclear utricle. Sometimes the homogeneous contents subsequently become finely granular. Chlorophyll-granules are occasionally formed in them. In the Rhizocarpeæ* they also contain starch-globules (?). At a later epoch a spermatic filament,† composed of albumen, is produced in each of these utricles.

3. *Nucleoli* (Kernchen).

The nucleoli were formerly regarded as solid bodies. I have already remarked upon this, some time ago, that certain phenomena connect themselves readily with the hypothesis that they are utricles.‡ The question is now, whether there are grounds for this assumption.

That the nucleoli are not mere aggregations of mucilage, follows from the circumstance that they always present themselves with a very definite border. Moreover, it is sometimes possible distinctly to perceive on them a membrane different from the contents. The contents are not always solid; they frequently exhibit one or more cavities; they are even frothy and granular, like the contents of the nuclear utricles and the cells. To these we may add the analogy with animal nucleoli, which are likewise utricles, and the other utricular structures of the cell-contents.

* Nägeli on Rhizocarpeæ, loc. cit.

† Nägeli on the Moving Spiral Filaments (spermatic filaments) in Ferns. (*Bewegliche Spiralfaden*, &c.) Schleiden u. Nägeli's Zeitschrift f. wiss. Bot., Heft i, p. 174 (1844).

‡ Nägeli on Cells, &c.; Ray Translation, 1845, p. 250.

The nucleoli occur inside the nuclear utricles and the spermatic utricles.* Nothing is known of their mode of origin. In animal nucleoli a process of division has been observed.†

The shape of the nucleoli is globular; at the moment when they originate by division, hemispherical. If they lie upon the membrane of the nuclear utricle, they are sometimes flattened on that side. The contents of the nucleoli are originally homogeneous and mucilaginous, and usually exhibit greater density than those of the nuclear or spermatic utricles; in rare cases they are less dense, causing the nucleolus to appear like a hollow space. The homogeneous contents of the nucleolus subsequently become frothy and granular; or they remain homogeneous and exhibit one or more cavities.

4. *Mucilage-* (*Protoplasm-*) *utricles* (Schleimbläschen).‡

These structures have hitherto been either overlooked, or taken for large mucilaginous granules or for globules of agglomerated mucilage. They may be seen beautifully, and in great abundance, in the Characeæ, where, together with amorphous masses of mucilage, they are the chief bodies seen to rotate. I have also seen them in the cells of many Algæ, of the leaves of Mosses and Hepaticæ, in the Ferns and the Phanerogamia. They do not present themselves constantly, and mostly but sparingly, 1—6 in a cell. They are more certain to be found in large cells than in small.

The mucilage-utricles are distinguished from the mucilaginous granules by their much more considerable size, by possessing a perfectly spherical shape and a smooth surface, and by refracting light less. That they are utricles,

* Nägeli on Cells, &c.; Ray Translation, 1845, pl. vii, fig. 11 *a*. Nägeli on Moving Filaments, &c., loc. cit. pl. iv, fig. 16, *a*, *b*, *c*.

† Kölliker, Entwick. der Cephalopoden, pl. vi, fig. 68.

‡ I refer the reader to the observation made in the preceding essay (p. 124) on the term "mucilage" (*schleim*).

and not homogeneous granules, follows from this:—1st, that when large enough, a membrane may be detected on them which is not coloured by iodine, while the contents become brown (pl. II, fig. 18); and 2d, that the mucilaginous contents may become frothy and hollow. The membrane becomes especially manifest, when the contracting contents separate in places from the membrane, in utricles which come in contact with water or tincture of iodine (fig. 18, *b*, *c*).

Little can be observed of the origin of the mucilage-utricles. They first appear as very minute globules of mucilage. It is possible that a small quantity of mucilage becomes agglomerated, individualized, and acquires a membranous covering. I have not observed a propagation of the mucilage-utricles.

The shape of the mucilage-utricles is spherical from the beginning, and it always remains so. The growth serves merely to expand the utricles uniformly.

The contents are originally homogeneous. They remain in this condition, or one or more hollow spaces appear in them.

The membrane is delicate, and seldom attains any considerable thickness. In *Chara* and *Nitella* only have I yet seen the mucilage-utricles with tougher membranes. The membrane is also thin here originally, and either invisible or only indistinct. By the application of iodine we may mostly succeed in seeing it more clearly. It then appears distinctly bordered by two lines (Fig. 18, *a*). At a later period minute points (*b*) appear on the outer surface, which with the increase of size show themselves to be little spines (*c*, *e*). In old utricles the spines disappear, and the outer surface of the membrane is irregular and uneven (*d*). During this the membrane has been constantly increasing in thickness.

Looking for an analogy for the spines just described, one might think of the cilia of the germ-cells of *Vaucheria*, and notice that the mucilage-utricles of the Characeæ likewise move (rotate), while the mucilage-utricles of other

plants have not this property. But the objection here applies that the mucilage-utricles rotate already before the spinous coat is observable on them. I do not think, therefore, that this has anything to do with the motion, and would rather conjecture that it is to be explained in the same way as the outer membrane of the pollen-granule.

5. *Proliferous utricles* (Brutbläschen.)

I give this name to those utricles in which, as in *Caulerpa*, the chlorophyll- and starch-granules originate.* I formerly called them "mucilage-cellules" (*schleim-zellchen*), but this name now requires alteration in respect to the rest of the nomenclature. Mettenius† saw the proliferous utricles in the radical hairs, and in the hairs of the upper surface of the leaf in *Salvinia*.

According to Hartig‡ the chlorophyll-granules originate in the so-called *euchrome-cells*, one kind of the so-called *ptychodal utricles*. The manner in which the researches were instituted, however, does not appear to me to afford the requisite guarantee, for results which can be depended on. It therefore still remains uncertain whether and where the proliferous utricles are found in the Phanerogamia.

The proliferous utricles first appear as homogeneous globules of mucilage. When they become larger, we detect a membrane on them, and mucilaginous contents, coloured yellow or brown by iodine. According to Mettenius, the utricles originate as minute amorphous granules. If this be intended to signify those minute homogeneous globules of mucilage, and not actual granules, it agrees with my observations. The globules differ from the mucilaginous granules by their regular, perfectly spherical form, their wholly smooth surface, and

* Nägeli on *Caulerpa*, Zeitschr. für wiss. Botanik., Heft i, pp. 184, 190.
† Beiträge zur Kenntniss der Rhizocarpeen, p. 51, pl. ii, figs. 42, 43.
‡ Das Leben der Pflanzenzelle, pp. 8-10.

the smaller power of refracting light. The exact process of the origin of the proliferous utricles is as yet unknown. Perhaps minute portions of the homogeneous mucilage of the cell become individualized, acquire a globular shape, and produce a membrane on their surface. Propagation has not yet been observed in the proliferous utricles.

The proliferous utricles lie free in the contents of their cell, and are always of globular shape. They increase in size up to a certain point.

The contents of the proliferous utricles at first consist of homogeneous mucilage; this frequently becomes granular. In it originate several globules of starch- or chlorophyll-granules.* The membrane of the proliferous utricles is subsequently dissolved, and the starch-globules and chlorophyll granules lie free in the cavity of the cell.

6. *Colour-utricles* (Farbbläschen).

These include the chlorophyll-granules, and the other coloured globules of the cell-sap. They have already here and there been called utricles, but no membrane has been shown to exist upon them. Formerly, the starch-globule, mostly present in their interior, was frequently taken for a cavity.

The following facts prove that the said structures are actually utricles: a whitish membrane, surrounding the green contents, may be clearly seen in the larger chlorophyll-utricles of the Algæ, of the leaves of Mosses, of the pro-embryo of Ferns (pl. II, fig. 10 *a*, *b*, *c*), of Characeæ (fig. 17), and, in favorable cases, in the leaves of Phanerogamia (fig. 12 *a*—*l*). When they lie close together, they do not become blended into a mass, but, like cells, acquire a parenchymatous form (fig. 11). By abnormal alteration (in the pro-embryo of Ferns (fig. 10 *d*, *e*, *f*), in the leaves of Mosses and Hepaticæ), they become

* On *Caulerpa prolifera*, by C. Nägeli; Zeitschrift. f. wiss. Bot., Heft i, 1844, pl. iii, fig. 19.

larger; the contents lose their colour, and pass into a colourless fluid containing granules; in this condition they are undistinguishable from minute cells. The contents of the chlorophyll-utricles undergo peculiar changes, which chiefly consist in the origin of one or more starch-globules (fig. 12). Green and red colour-vesicles manifest growth, and in the course of this their shape is altered in various ways. Finally, the chlorophyll-utricles divide like cells (fig. 10 *c*).

Since Mohl's researches* the chlorophyll-utricles have commonly been regarded as a nucleus of one or more starch-granules, on which chlorophyll has been deposited as a coating. This view presupposes that the starch-granules exist first, and that they are afterwards coated with chlorophyll. But the transition of starch-globules into chlorophyll-granules has nowhere been seen. On the other hand, chlorophyll-utricles not unfrequently occur in the Algæ without a trace of starch in their interior. In some Algæ, moreover, as well as in higher plants, the origin and growth of the starch-globules may be traced, in the interior of the chlorophyll-utricles, up to the absorption of these latter.

The colour-utricles are best named according to their colour; green, red, blue, or yellow colour-utricles, or even with one word; green utricles (chlorophyll-utricles), red utricles, &c.

I know nothing of the origin of colour-utricles free in the cell-contents. They appear as minute (green or red) granules, which, after they have reached a sufficient size, display an utricular structure (fig. 10, *a*, *b*; fig. 12; fig. 17). They originate by the division of a parent-utricle. This becomes elongated, divides by a wall, and separates into two new colour-utricles (fig. 10 *c*).

I have seen the division of the green colour-utricles in Algæ (e. g. in *Bryopsis Balbisiana*, *Valonia ovalis*), in the pro-embryo of Ferns, and in *Nitella*. This division sometimes presents such an appearance that we only see

* Untersuchung. üb. die Anatom. Verhältnisse des Chlorophylls. (Dissertation, 1837, Verm. Schrift. p. 349.)

a circular constriction, which advances inwards, and at last parts the chlorophyll-utricle into two. In other cases a septum is first perceived, and the apparent constriction is recognised to be simply a result of the retraction of the already-formed secondary utricles from each other. Thus a conviction is readily attained that in the first case the septum is overlooked on account of its delicacy, or its oblique position.

It may, indeed, be objected that the said division is merely apparent, and produced artificially by the close apposition of two colour-utricles. Such a condition is actually produced artificially, when two utricles come so close together under the microscope, that they become flattened by their mutual pressure. It is therefore a question whether to take account of that apparent division of the chlorophyll-utricle in the vegetable-cell, or not. *Nitella* has furnished me with evidence for it.

I examined the terminal cell of the leaves in various stages of growth in the same individual, in *Nitella syncarpa*, namely, 1st, one measuring ·080 of a line; 2d, one = ·500; 3d, one = 1·5; and 4th, one = 6 lines in length. The diameters were from ·030 to ·050, ·060, and ·090 of a line. The chlorophyll-utricles lay in vertical rows on the walls. They were all of about equal size, and exhibited a perfectly regular shape, both in the young and in the old cells. Some appeared to be in the commencement of the act of division. Actual division and propagation must take place if the number of chlorophyll-utricles increase from the young to the old cells, since of any very minute utricles which might originate free among the others, I saw no trace, either between the utricles of the same row, or between the rows. Now I counted the rows, and found constantly about eighty of them, both in the young and old cells. No multiplication of the rows takes place; in fact I did not see any chlorophyll-utricle divide perpendicularly into two utricles lying side by side. On the contrary, I found in the first and shortest of the four cells mentioned, 40 utricles in a row;

in the second cell, 150; in the third, 500; and in the fourth, and longest cell, 2000. During the growth of the cell from a length = ·080 of a line to 6 lines, the number of chlorophyll-utricles had increased in each row from 40 to 2000, and in the whole cell from 3200 to 160,000. Consequently, while the cell became seventy-five times longer, the chorophyll-utricles increased about fiftyfold.

I found the like in the cells of the stem of the same plant. In a length of 1·3, and a diameter of ·14 of a line, I counted about 160 rows, in each row about 325 utricles; in one about 20 lines long and ·2 in diameter, again about 160 rows, but some 3500 utricles in each row; and lastly, in a cell 30 lines long, and of a diameter = ·24, I found about 160 rows, and some 6700 chlorophyll-utricles in each row. Here also the utricles were of tolerably equal size, and in regular arrangement in the cell. Individuals exhibited transverse division; but I saw no young, minute utricles between the others, so that here also *the increase in number could only be effected by division.* This increase amounted to about twenty times the number, while the cell increased about twenty-three times in length.

If the colour-utricles originate free in the cell-contents, their shape is at first globular; if they are produced by the division of a parent-utricle, at first hemispherical or semi-ellipsoidal. In the latter case they soon assume a globular form as they separate from each other. If the utricles, as rarely happens, remain free, so that they swim in the cell-contents, they retain their globular form. Usually they apply themselves upon the wall, whereby their form is more or less altered, since they become more or less flattened. Their section is then either almost round, oval, hemispherical, semi-elliptical, or flatly compressed.

The alteration of form which the colour-utricles undergo during their growth consists not only of a mere flattening of greater or less extent, which we see in the side view

(or section), but also in the acquirement of a different shape, as seen in front. Here also the utricles at first appear round. They either remain round or become elliptical. If they lie close together, they become parenchymatous (fig. 11, fig. 13). If colour-utricles increase in length, this takes place either parallel to the long axis of the cell, or if they lie in a circulation thread, in the direction of the current. I have observed the latter in the Algæ (e. g. in *Conferva glomerata marina*). On the inner surface of the cell-wall lies a network of mucilaginous filaments. The chlorophyll-utricles form simple rows in the lines of the reticulation (fig. 16). They extend in length in the direction of the lines, and may become lanceolate, or even linear. Those lying in the angles of the network assume a triangular form; the angles are more or less drawn out in the direction of the filaments of circulation towards which they are turned. In Florideæ (e.g. in *Ceramium diaphanum*) I saw the red utricles, which were originally round, elongate so much in the direction of the longitudinal diameter of the cell, that they had the appearance of long fibres. In this case their transverse diameter diminished considerably.

The growth of the colour-utricles presents great similarity to the universal growth of cells. It exhibits on the one side the transition from the globular to the tabular form, on the other from the globular to the elongated, fusiform or filamentous shape. They may also become elongated into separate processes, almost like stellate cells. Moreover, by pressure they may become parenchymatous.

The expansion which is connected with the growth of the colour-utricles exhibits great quantitative differences. It is greatest in those which originate free in the cell-contents, since they appear first as very minute granules. It is less in those which have been produced by the division of a parent-utricle; here it amounts, as a rule, to two to three times the original length and breadth; otherwise the growth is not always connected with an increase of size in all diameters; in tabular and very much flattened

chlorophyll-utricles, the smallest diameter is shorter than it was at first; in the thin, fibre-like red utricles both the shorter diameters are very considerably diminished.

The contents of the colour-utricles are at first always homogeneous, green (fig. 12 *a*; 13 *a*), red, yellow, or blue. They may present different characters during the life of the utricle.

In the first place, the contents remain for the whole period homogeneous and coloured, without alteration, or at least without any that can be noticed.

Or, secondly, one or more very minute granules become visible in the contents, which are permanent in this stage, and the nature of which cannot be made out, on account of the small size. Probably they are starch-globules, as would result from the following. In a third condition of the contents, minute granules of the same kind appear, but are somewhat larger, and appear as whitish globules, coloured violet or blue by iodine (fig. 10, *a*, *b*, *c*; fig. 11; fig. 13; fig. 17). Mohl thinks that the violet tinge is produced by the brown colouring of the surrounding green contents. It appears certain to me, however, that this is proper to the starch-globules. Even before the treatment with iodine a difference is observable in the latter, for they refract light more strongly and the others more weakly. If they refract light in this manner, they will acquire the blue colour, in spite of the surrounding chlorophyll; if the refraction is less, the colour is violet. These starch-globules are very frequently solitary in an utricle; sometimes, however, from two to five are present. They only occupy a small portion of the cavity of the utricle.

A third condition of the contents consists in the following: As before, minute granules first become visible in the homogeneous, coloured contents. They increase in size, and at last almost wholly fill the utricles, so that merely a thin layer of colour remains investing the starch-globule (fig. 12 *i*). If, as is generally the case here, the membrane of the utricle is indistinct, it appears as though

the starch-globule were only coated with colouring matter (chlorophyll).

A fifth condition. One or more starch-globules originate in the colouring matter (fig. 12, *a*—*f*), which increase in size, and finally almost fill the utricle (fig. 12, *g*—*l*). The colouring matter (chlorophyll) by degrees vanishes, at last entirely, and finally the membrane also of the utricle is dissolved, and the starch-globules lie free in the cell (fig. 12, *m*, *n*).

These are the principal alterations which take place in the contents of the colour-utricles. I have chiefly observed them in chlorophyll-utricles. Nothing general can be said respecting the distribution of the forms mentioned. As a rule, all or many are met with in the same Natural Order. I have, however, met with green utricles with contents remaining homogeneous, and those minute starch-globules, coloured blue by iodine, much more frequently in the Algæ and Mosses; those with large starch-globules, coloured blue by iodine, more frequently in the higher plants. The red-utricles of the Florideæ generally exhibit only homogeneous red contents. The yellow and blue utricles I am not yet sufficiently acquainted with.

It still remains to be noticed that globules occur, in rare instances, in the place of the starch, inside the colour-utricles, which are either not coloured at all by iodine, or become yellow. In my opinion they are composed of a substance analogous to starch; allied to gelatine and inuline. But I cannot agree with Schleiden, who says, that chlorophyll (the chlorophyll-globules) often invests starch, and also often other substances.* Beyond starch (as ordinarily), and the globules just mentioned (which occur exceptionally), I have never yet met with any known solid product in the chlorophyll-utricles, for instance, not even oil- or mucilage-granules, &c.

The homogeneous colouring matter of the colour-utri-

* Grundzüge, 2d ed. i, p. 190.

cles also undergoes an alteration occasionally, consisting in the colour becoming fainter; moreover, even in the transition of one colour into another. In many genera of Florideæ it is rather common for the red colour-utricles to become subsequently green or yellowish green.

The colour-utricles undergo dissolution in three ways: 1, by propagation; 2, by the starch-globules inclosed within them gradually displacing the colouring matter, and at length causing the absorption of the membrane; and, 3, by changes in the cell-contents, inducing a solution of the contents and membrane.

When the solution of the colour-utricles is brought about by changes in the cell-contents, they usually become detached from the cell-wall, pass into the interior of the cavity of the cell, and acquire a more or less perfectly globular form. The colouring matter becomes granular, loses its colour, and is then dissolved, the membrane at the same time disappearing. In decaying cells of the pro-embryo of the Ferns, as well as occasionally in decaying cells of the leaves of the Hepaticæ and Mosses, I have seen the chlorophyll-utricles expand considerably during this process (in *Pteris nemoralis* from ·006 to ·008 of a line). The chlorophyll dissolved into minute dark granules which swam in a colourless fluid. The membrane of the utricle was here very distinct. (Fig. 10, *d*, *e*, *f*.)

7. *Starch-utricles, Starch-granules.*

Three different opinions have been expressed as to the origin and nature of the starch-granules. According to one, they consist of a cell-like envelope and fluid contents. According to a second, a nucleus is first formed, around which concentric layers are deposited on the outside. According to a third view, the formation of the layers proceeds from without inwards.

The first opinion, Raspail's, appears in a peculiar form, resulting from his theory of cells. The starch-grain is a

cell or an utricle originally attached to the wall of the cell, and produced by this. The envelope is starch; the contents gummy (gummös) and semifluid. Microscopic investigation is in opposition to this view.

The second opinion, as champions of which Fritsche and Schleiden may be named, maintain, on chemical grounds, the fundamental point, that, with the exception of the nucleus, the layers are wholly composed of the same chemical substance. The outermost layers are impregnated with foreign matters, and are thus rendered insoluble in water. Especial difficulties occur in this view, both in chemical and physiological respects, in explaining the nucleus, which, according to the authors mentioned, on one hand, is a hollow space, on the other, contains neither sugar, gum, nor starch. What then is the thing upon which the first and innermost layer of starch is deposited.

The third opinion has been recently promulgated by Munter.* The innermost layers are the softest, and thus the youngest. Very good; but the origin of the outermost and earliest layers of starch is here forgotten; upon what are these deposited? Of course there is no difficulty about those succeeding. Moreover, a fact which Munter states that he has ascertained in the starch-grains of *Gloriosa superba*, stands in strange contradiction to this view, namely, "that an organic compound also may appear in a crystalline form;" and then the term of "starch-concretions" (*stärkedrusen*) proposed for these so-called agglomerated granules is just as inapplicable.

In my opinion, the starch-grains are utricles, and consist, like the other utricles, of a membrane and fluid contents. Concentric layers are deposited on the inside of the membrane as in lignifying cells. The cavity of the utricle (the so-called nucleus) thus becomes reduced to a most minute excavation, which is always filled with fluid.

* Botanische Zeitung, 1845, p. 193.

The grounds for the opinion here expressed are as follows: In many starch-grains a layer different from the rest, and surrounding the nucleus, may be more or less clearly perceived. In some, this shows itself as a tolerably thick membrane which iodine does not colour (fig. 14). The starch-grains are hollow; sometimes the cavity is so large that the starch invests the membrane merely as a thin layer (fig. 15). The layers become softer and contain more water toward the interior, and are tougher and more solid toward the exterior; from analogy to the lignifying layers of cells, the softer are to be considered as the younger, the harder the older.

Nothing is known of the origin and propagation of the starch-utricles, except what regards the external conditions under which they are produced; we know that they may be formed free in the cell, and this either in mucilage or in chlorophyll; in utricles, namely, in the interior of nuclear utricles (in the Fucoideæ*), of prolific utricles (*Caulerpa*), and of colour-utricles (pl. II, fig. 10, 11, 12, 13, 17).

The shape in which the starch-utricles appear is probably at first always spherical. They may remain spherical or extend lengthways, so as to become almost cylindrical, or grow in a plane, so as to assume a tabular shape. The form of the full-grown starch-grains is exceedingly varied and mostly irregular, so, however, that granules which originate free, are always bounded by one single curved surface.

The granules lie free or united in groups of from two to twelve, and even more. A group of this kind is, not very aptly, termed a compound grain. The individual grains or utricles are parenchymatous; the sides directed towards the interior of the group are plane, those which form the surface of it are curved (convex outwards). All the grains united together in a single heap have been produced in one utricle. They are at first spherical, but from the reciprocal pressure which they undergo, in consequence of their growth, they acquire a parenchymatous

* Nägeli on Cell-Formation; Part I, Ray Trans. 1845, pl. vi, fig. 16.

form, and through this same pressure adhere together as a tissue (fig. 12 *g*). If the utricle then becomes absorbed, the grains either remain united in a group (fig. 12 *n*) or separate. Since, however, they have acquired a solid structure by the formation of layers of lignification, they do not reassume the globular form, but remain polygonal and exhibit a shape which has a crystalline appearance, without, on that account, being actually crystals (fig. 14).

I do not mean, however, that the starch-grains which have originated together in the same utricle, necessarily always assume a parenchymatous shape; they only do this when they are contained in proportionate number or size (to the size of the utricle). If they lie more loosely in the utricle, they always remain isolated and retain their rounded surface. Thus I have never seen starch-grains become properly parenchymatous, either in the nuclear or prolific utricles. In the green utricles, also, I have likewise often seen them remain globular, even when a number have originated together in one utricle.

Those starch-grains, therefore, which lie separate and are bounded by a single curved surface, have originated either free in the cell, isolated in utricles, or in numbers loosely arranged in utricles. Those which lie separate and have one or more plane surfaces or angles, have originated in numbers, closely packed in a green utricle.

In like manner the granules united into a mass have been formed together in a green utricle.

The original contents of the starch-utricles are unknown. As soon as they have attained a sufficient size to allow of their being investigated, they are coloured blue, violet, or red, by iodine. The formation of layers, therefore, begins very early, and it must thence be assumed that the outermost and first layers expand considerably in surface until the growth of the utricle is completed. There is nothing whatever opposed to this hypothesis, since the layers are at first in a soft, semifluid condition, and since the cell-membranes and the earliest of its layers of thickening are likewise capable of considerable expansion.

Consequently starch-utricles and cells agree in this: that

the membrane of both begins to be thickened soon after its production. They are distinguished by the fact that in the starch-utricles this thickening is relatively much more considerable, even at the very beginning, than in the cell.

The structure of the starch-utricles first becomes clear when they have acquired a greater size; this is: a membrane, probably composed of gelatine, layers formed of starch, and a cavity filled with watery fluid. The membrane is more or less distinct; when it is thick enough we may perceive that it remains uncoloured in the treatment with iodine, while the layers become blue or violet (fig. 14, 15).

The layers are formed like the thickening layers of the cell; the concentric lines are to be explained in the same way as these. The layers are composed of starch throughout their entire thickness. They decrease in solidity from without inward, and contain more water in the reversed order. Hot water and acids cause them to swell up very much, and they frequently tear in consequence of an unequal expansion, either merely in the interior, or from within outward. But that an air-bubble originates in the cavity through the action of sulphuric acid, as has been asserted, I have not seen, neither can I conceive how sulphuric acid could produce an air-bubble here, by abstraction of water. For the acid does not draw out the water like some pump or exhausting apparatus, but when the acid is applied to the starch-grain a reciprocation of currents is set up, according to the law of endosmosis and exosmosis, through the layers and the membrane, the acid passing in, and a portion of the fluid of the cavity and the layers going out. If more fluid passed out than in, and the starch-utricle could not contract in a corresponding degree, the only consequence would be that the diminution of density, beginning in the interior, would cause an increased flow inwards from without. Now the swelling up of the utricle proves exactly the contrary, namely, that more fluid passes in than out.

The cavity of the starch-utricle is sometimes larger, sometimes smaller. In a given size of the utricle of

course its size is in inverse proportion to the thickness of the layers. In many grains the cavity is reduced to a minimum. These grains correspond to the cells of the stony concretions of pears, and completely lignified liber-cells. In other grains the cavity is of considerable size. The thickness of the deposited layer of starch may be so small that the starch-utricle resembles a cell with moderately-thickened walls (fig. 15). I found such a condition not unfrequently in the pith and rind of the fruit panicle of *Vitis*. The cavity is filled with an almost colourless fluid, which doubtless is no simple chemical substance, but contains formative matter, such as gum, sugar, and quaternary compounds, although in small quantity.

8. *General Retrospect.*

We have found various organic structures in the cell-contents possessing, in all their phenomena, a great resemblance to the cell itself. The general term for those structures, partly on account of this similarity, partly to express the actual difference, may most fitly be *utricle*.

The utricle agrees with the cell* in the following characters. *It probably originates by the isolation of a (minute) portion of organic substance, which becomes coated with a membrane. Therefore from the very origin there appears a distinction between contents and membrane. The utricle grows both in its membrane and its contents; and, in the course of this, changes its shape in manifold ways. The membrane expands and becomes thickened by the deposition of layers in the interior. The contents are metamorphosed, and produce new organic forms. Finally, the utricle propagates.*

Thus nothing occurs to the cell which is not found in the utricle, at least in one or a portion of the kinds of utricle. Moreover, we see that exactly the essential peculiarities of the cell, *the proper membrane and the transformable contents*, occur in all utricles. The identity between cell and utricle is, therefore, tolerably manifest.

* See the preceding Essay (on Cell-Formation).

The *distinction* between the two is more difficult to find, especially because the origin of the utricle is not yet sufficiently made out. I believe, however, that even with our present knowledge, the distinction may be at least so far established, that cell and utricle appear as absolute, distinct conceptions. The comparison may take into consideration either the relation of the two structures to the individual plant, or the two structures independently of general relations.

In reference to the relation to the vegetable organism, cell and utricle exhibit the following distinction. The cell is the elementary organ, which takes part *immediately* in the formation of a tissue. The plant first becomes independent with the cell. It developes through the formation and growth of cells; it lives through the cells. The utricle, on the other hand, is an elementary organ which takes part only *mediately* in the origin, structure, and life of the plant, because the utricle is merely a part of the cell. Consequently we may call the cell the *immediate*, the utricle the *mediate* elementary organ of the plant.

Considering cell and utricle independently, as individual organisms, we can at present establish merely the following distinction. The cell needs for its production a nucleus, formed previously; it is formed around a portion of organic cell-contents in which a nucleus is inclosed.* The utricles, on the contrary, never originate around a nucleus, only the nuclear utricles originate around a nucleolus. We may accordingly define the cell and the utricle in the following terms:

The cell is an individual quantity of contents, inclosed by a homogeneous membrane, and individualized through the influence of a nuclear utricle; it is the immediate elementary organ of the vegetable organism.

The utricle is an individual quantity of contents, in-

* I have shown, in the preceding Essay, that in the first place a nucleus is produced which individualizes a greater or smaller quantity of the surrounding contents, through attraction, and that this individualized portion of contents acquires a membranous coat upon its surface.

closed by a homogeneous membrane, and individualized without the influence of a nuclear utricle; it is merely the mediate elementary organ of the vegetable organism.

The following kinds of utricle may be distinguished:

1. *Nuclear utricle, Nucleus. It originates under the influence of a nucleolus, and contains, at least in the earlier periods of its life, scarcely anything, excepting one or more nucleoli* (*colourless* or *coloured*), *besides mucilage. It occurs* (with the exception of those which originate in a parent-cell) *only immediately in the cell* (not in another utricle).

2. *Spermatic utricle. It originates,* probably, like the nuclear utricle, in like manner, *under the influence of a nucleolus. It contains principally mucilage, and produces a spermatic filament in its interior.* The spermatic utricle probably occurs originally merely in cells, and in any case never inside other utricles.

3. *Nucleolus. It contains mucilage, and occurs* (sometimes with the exception of those around which the nuclear utricle has not yet been formed) *only inside the nuclear utricle.*

4. *Mucilage-utricle. It contains mucilage, but no nucleolus, and occurs immediately in the cell* (not in other utricles).

5. *Proliferous utricle. It at first contains mucilage, but no nucleolus, subsequently colour- or starch-utricles, which, after its solution, become free.* It occurs only free in the cell (not in other utricles).

6. *Colour-utricle. It contains colouring matter, but no nucleolus,* and may be named according to the colour. It frequently contains also starch-utricles. It occurs free in the cell as well as in old nuclear and proliferous utricles.

7. *Starch-utricle, starch-granule. It contains layers of thickening of deposited starch,* and occurs free in the cells, as well as in old nuclear, colour, and proliferous utricles.

ANNUAL REPORT

ON RESEARCHES IN

PHYSIOLOGICAL BOTANY,

DURING THE YEARS 1844 AND 1845.

BY DR. H. F. LINK,

DIRECTOR OF THE ROYAL BOTANIC GARDEN OF BERLIN.

PHYSIOLOGICAL BOTANY.

GENERAL OBSERVATIONS.

Physiology, and with it Physiological Botany, were, it was thought, quietly making considerable progress, since the number of contributors continually increased, and though of course opinions differed, none were maintained with any remarkable violence. Then certain individuals appeared who endeavoured to disturb this tranquillity, and not only advocated their own opinions with great violence, but attacked those who thought differently, challenged them, and even in some cases insulted them. I shall especially mention three of these—Liebig, Gaudichaud, and Schleiden. All three write well, Liebig excellently so; not one is wanting in genius and ingenuity; in their zeal, however, they have not all been able to command themselves, but have given way to a violence which, although not hindering them for any time, perhaps even aiding them in acquiring speedy renown, is nevertheless always injurious to the cause which they are anxious to advocate.

Liebig says, in the first edition of his celebrated book, 'Organic Chemistry in its Application to Agriculture and Physiology' (Brunswick, 1840), p. 35, "As soon as physiologists meet with the mysterious vital force in any phenomenon, they renounce their senses and faculties; the eye, the understanding, the judgment, and the reflective faculties, all are paralysed as soon as a phenomenon is declared to be incomprehensible." Now this has not really been the case; they have indeed very

rarely declared a phenomenon to be incomprehensible, whilst they have frequently erred in the contrary direction; but supposing they had done so, they could always say confidently to those philosophers who wish to believe that everything depends upon mechanics, and forces which act mechanically—"Tell us, ye slanderers, are you then acquainted with the fundamental theory of the whole of your mechanics; do you understand the cause of motion even in the slightest degree? Is it not the most incomprehensible of all the phenomena with which we are surrounded?" And even if it were answered that it was the first, the most common, and the most certain empirical knowledge upon which anything could be based with certainty, it might be easily replied, that the same was also the case with vitality, for we cannot even start the question of the cause of motion without living. What has just been stated might be recommended to many philosophers, especially in foreign countries, as a subject for careful consideration, when they urge mechanical explanations to the very utmost—when, as it were, they are suspended in the air without any support. Dutrochet may serve as an example; he attempts to explain mechanically all the motions of plants, by means of endosmose and exosmose, by the influx and egress of the fluids in the cells and vessels which permeate the membranes, fill and distend the cells, and produce movements by means of this distension, and even by flowing out produce collapse and motion in the opposite direction. Yet the causes of the phenomena of endosmose and exosmose, upon which this theory is based, have by no means been ascertained; it has certainly not been proved that the exchange of matters in solution through the unvitalised membrane, which we find in these experiments, occurs through the living membrane of the cells in plants, for the simple reason, that we do not find that those cells which are situated near each other contain different fluids, by means of which this exchange could be effected; we cannot understand how the gradual influx and egress

occurring in endosmosis and exosmosis can produce rapid movements, especially those of *Mimosa pudica*, to which Dutrochet applies his theory; lastly, it cannot be explained by mechanical laws how this expansion and contraction of the cells becomes capable of raising whole portions of plants. Still this is repeated by the majority, and De Candolle was once at their head; but I must cease here, to avoid falling into the very error that I have attributed to others.

Is it not better, instead of retarding the progress of science by such explanations and their details, to recur at once to a vital force, the determination of the laws of which will remain our object, and our not unfounded hope?

To a certain extent, but to a certain extent only, has Liebig returned to the ordinary path in regard to the vital force. In his book, 'Organic Chemistry in its Application to Physiology and Pathology' (translated by Dr. Gregory, London, 1842), in the third part, speaking of the phenomena of motion in the animal organism (p. 196), he says: "If the vital phenomena be considered as manifestations of a peculiar force, then the effects of this force must be regulated by certain laws, which laws may be investigated; and these laws must be in harmony with the universal laws of resistance and motion, which preserve in their courses the worlds of our own and other systems, and which also determine changes of form and structure in material bodies, altogether independently of the matter in which vital activity appears to reside, or of the form in which vitality is manifested." The author is by no means clear in his views of the pretended vital force. What is meant by "must be in harmony?" Are they the same, or do they only resemble each other? We do not see why they might not be directly opposed, or totally different. But the author's views are not clear even upon a purely physical force, the attraction of gravitation. He says (l. c. p. 201): "If it (the stone) fall from a certain height, it makes a permanent impression on the spot on which it falls; if it fall from a still

greater height (during a longer time), it perforates the table; its own motion is communicated to a certain number of the particles of the wood, which now fall along with the stone itself. The stone, while at rest, possessed none of these properties. The velocity of the falling body is always the effect of the moving force, and is, *cæteris paribus*, proportional to the attraction of gravitation. A body falling freely acquires, at the end of one second, a velocity of 30 feet. The same body, if falling on the moon, would acquire, in one second, only a velocity of $\frac{30}{3600}$ths of a foot, $= 0{\cdot}1$ inch, because in the moon, the intensity of gravitation (the pressure acting on the body, the moving power) is 3600 times less."

We shall not dwell upon the individual expressions which are not always accurately applied, but shall merely ask, Why does Liebig omit to notice the law of inertia, upon which all mechanical determinations are based, which causes the velocity of a falling body to increase constantly in proportion to the duration of its fall. Galileo applied it without recognising it; when he discovered the law, that the space through which a body falls is as the square of the time in which it falls. Newton called it the law of inertia, placed it at the head of his 'Principia Philosophiæ Naturalis Mathematica,' and expressed it as follows: "A body continues in its state of rest or motion, in the same direction and with the same velocity, until some motive force compels it to change this state." It may be perhaps attributed to the physio-philosophers of Germany that they have forgotten, or at least overlooked, this law in the explanation of natural phenomena; in fact, that natural philosophers, who, like Liebig, have no respect for philosophy, make no mention of this law. Not only does it explain the increased velocity acquired by a falling body, but even the most common, the daily phenomena occurring upon the moving globe, could not be explained without it—such, e. g. as the fall of a stone from a house or a tower; why, when allowed to fall from the west side of a house it does not reach the earth

far behind the house; because the house being situated upon the globe, which is in rapid motion, flies away as it were from it; and lastly why, when a stone falls from a high tower, a deviation ensues, because the summit of the tower is in more rapid motion than the earth at its foot, towards which the stone descends. But I feel ashamed to be teaching matters which belong to elementary school-instruction. Newton correctly ascribed to matter inertia, and not a property of passive resistance, as some philosophers attribute to it; for so long as the matter is subjected to this law, it has no property; it is in a perfect state of indifference; it cannot assume a state of motion when at rest; it cannot, in the slightest degree, alter any motion which has been imparted to it from without, and without its co-operation; in short, if we may use the expression, it is lifeless. Here, then, we have a certain and definite character of inactivity, from which we may start, and from which we must start, in the consideration of vitality and the vital force. The antithesis of vitality, in contrast with this state of inertia, this indifference, is clear; a body must be called living when capable of spontaneously assuming a state of motion from one of rest, or when capable of changing or in any way determining its motion; whence what is to be considered as the vital force soon follows. Let us take one application of what we have stated: Is the universal attractive force a vital force? The answer is negative; the body approximates to another, merely inasmuch as it is attracted; it does not then set itself in motion; it does not determine its motion by any power of its own; this is merely determined by the attraction of some other body. Hence alone is astronomy enabled to calculate with certainty and accuracy the motions of the celestial bodies. This force can certainly set other bodies in motion, but not that body in which it exists, and through which it acts. We cannot in any way understand why there should not be forces capable of setting the bodies in which they exist in motion, since we find motions in living bodies which

cannot be derived from external forces. These are denominated vital forces. They are not in the least more incomprehensible than the force of attraction; in fact they are less so. Newton found, with regard to the force of attraction, that the intensity with which it acts upon a body is inversely proportional to the square of the distance of the body from the centre of attraction. But has this law been shown to exist in the case of other forces? Does it apply to cohesion, elasticity, magnetism, &c.?

Liebig says, in his 'Chemical Letters' (Heidelberg, 1844, p. 18), "Medical writers and kindred minds are annoyed at the great simplicity of the truth, although they have not succeeded in practically applying it, notwithstanding all their pains; they therefore give us the most improbable views, and by the term vital force they understand a wonderful thing, by means of which they explain everything which they do not understand; by a thoroughly incomprehensible and indefinite something, everything which is incomprehensible is explained!"

That bodies combine chemically in definite proportions only is undoubtedly a law of combination, but I should like to know according to what law chemical decompositions take place. Is the chemistry of decomposition anything more than a specification of the results of experiments made upon individual bodies, each individual experiment being calculated according to a fixed form? Is the word affinity anything more than a word? Nothing is explained in chemistry; everything in chemistry is incomprehensible. The vital force, on the other hand, acknowledges general laws. There is the law of periodicity, which is the direct antithesis of the law of inertia, according to which motion increases to a certain extent, and then again diminishes; there is the law of habit, according to which reaction is not always equal to action, but diminishes in proportion to the frequency of the repetition of reaction. However, I am not writing upon general physiology.

Liebig's work, mentioned above (Organic Chemistry

in its Application to Physiology and Pathology) is still an excellent one. It shows us how the proportion of the constituents of the fluids, and of the solids of the animal body, may be deduced from the proportions of the constituents of the nutritive matters. This is certainly the first step towards explaining the nutrition of the animal body and its secretions; but it is only the first step, and we are ignorant of the decomposing and the combining forces. They appear to belong to physical rather than vital forces; and even when we have ascertained these, the ultimate means by which these forces are set in action remain to be determined. And for the physician, the principal point is to increase the activity of these forces; or when it is too great, to diminish it. We must agree with Liebig, nay, we might even censure with his violence, when we see how many physiologists misapply the word life; but this blame does not attach to all physiologists, when they used the term vital force correctly, i. e. when they apply it to those cases in which chemical forces cease to act in their natural manner. It is very necessary to advance by means of physics and chemistry as far as possible, but we must not trust more to these two sciences than they are capable of effecting.

Gaudichaud has come forward with great decision against Mirbel in the Academy of Sciences at Paris. Offended by some expressions which Mirbel made use of in his 'Memoir upon the Structure of the Stem of the Date-palm,' and which Gaudichaud correctly considered as directed against him, immediately after the reading of the memoir, he briefly protested against it, and declared Mirbel's system to be incorrect. There also appeared soon after, in the year 1843, two memoirs justifying his protest. They have been spoken of in the 'Annual Report' for 1842-3, as have also his *Recherches générales sur l'Organographie*, &c. *des Plantes* in the 'Annual Report' for 1841. In the 'Comptes Rendus' for 1844, we now have the third and fourth protests against Mirbel (I, pp. 597 and 899). He has not yielded. In 1844

Mirbel read a memoir upon the Structure of the Stem of *Dracæna Australis*, of which we shall speak hereafter; and in the 'Comptes Rendus' for 1845, we find not less than seven papers against Mirbel's memoir. Many years ago even, Gaudichaud was so engrossed with his own theory, that he would scarcely listen to objections made orally to him, or which referred to investigations which he was going subsequently to publish. His style is brief, almost aphoristic, and positive, nevertheless it is not free from repetition; but he says, by way of exculpation, "I must continue to repeat until my system is generally received." From his obstinacy it may be expected that he will not yield.

Gaudichaud has also evinced this pertinacity in his life. He was an apothecary, accompanied, as pharmaceutical-botanist, a voyage of discovery under the command of Freycinet, and, in September 1817, went on board the corvette *Urania*, which was shipwrecked on the 14th of February, 1820, at the Maluines. It sailed from Port Jackson southwards, next struck upon some ice-islands, then rounded Cape Horn, and cast anchor in the Bay of Good Success, at Terra del Fuego. A violent gale of wind compelled them to cut their cable and stand out to sea. Some days afterwards, during the most beautiful weather, the ship was driven upon some concealed rocks near the Maluines, and twelve hours afterwards upon the sand in the bay or creek called by the French the Bay of Solitude, where it still remains. It was four o'clock in the afternoon when it went upon the rocks, and four o'clock in the morning when it was wrecked on the sand-bank and sunk. The interval between these two events was a dreadful night of anxiety and danger. Gaudichaud was fortunately saved, but the whole of his collections were submerged, and could not be removed until they had been from thirty-six to forty hours under water. He was obliged to wash every packet, in fact every sheet, in fresh water, and to dry them; and thus during the four months which he passed there, he was enabled to save

about 4000 specimens of plants out of 6000. He returned to France in December 1820, with the corvette *La Physicienne*, which the government had purchased at the Maluines. He wrote there the botanical part of the description of the voyage, and also planned his 'Organography and Physiology of Plants.' In 1831 he went in the frigate *Herminie*, under command of Villeneuve Bargemont, to the coast of South America. The frigate sailed twice round Cape Horn, and returned in 1832 from Rio de Janeiro to France. Gaudichaud, however, obtained permission to remain in the Brazils, from which country he returned to Toulon in the corvette *La Bonite*, Captain Durand, in June 1843. In April 1835, he delivered his remarks on the 'Organography, Organogeny, and Physiology of Plants' to the Institute; and in December of that year, on the day on which the Monthyon-prize was awarded to him, he left Paris to make his third voyage in the corvette *La Bonite*. He started from Toulon in February 1836, and returned in the same ship at the end of the year 1837. I have derived this information from the account of his life in the 'Revue générale Biographique,' which adds further: "Gaudichaud, that energetic man, born with the Revolution in 1789, and grown up in it, has fought several duels, but," it adds, "all who were acquainted with M. Gaudichaud know that he never took the lead in these affairs." I have not given these details of Gaudichaud's life here entirely without an object.

"What," says he (Compt. rend., 1844, 1,598) "is a Monocotyledonous plant at its very origin, e. g. a Date-palm? an animated cell, which produces an embryo or a bud. An embryo, as all botanists now know, is a free, isolated, independent cell. This embryo, or this primitive phyton, is a distinct individual, possessing its own peculiar organization, and its peculiar functions. The first individual soon produces a second; the second, a third; the third, a fourth, and so on, during the whole life of the plant. As the embryo possesses its organiza-

tion and its peculiar normal functions, so will also the individuals produced by it, and by all those which follow it, and which possess their own separately, i. e. modified according to the stages of their development and their age, the second being directly and constantly grafted upon the first; the third upon the second, and so on, each one being grafted upon the other. The first individual, the embryo, derives the principles of its existence from without, from water, air, light and heat, but especially from the albuminous body (perisperm), when it is present, which nourishes the embryo, and is thus absorbed; the second is nourished by the first; the third by the second and the first, and the fourth by the three others, as well as by the elements previously named; hence it follows, that when the phytons are perfectly developed, the first remains very weak; the second is somewhat stronger; the third is still stronger; and that all the subsequent ones become stronger and stronger, as also more complicated in form, and consequently in functions, until we arrive at the normal leaf, which has attained the highest stage of organization."

Gaudichaud says, all botanists now know that the embryo is a bud, whence it may be readily deduced, that the bud is just the same as the embryo, and must have roots like it. But this is not the case, the embryo is not a bud, nor the bud an embryo. There is an old and every-day observation, which I am accustomed briefly to explain in the following manner: the embryo—produced by impregnation—propagates the species; the bud, the individual. A branch with buds, from a Borsdorf apple-tree, when grafted always produces Borsdorf apples, whilst the seed of a Borsdorf apple never does so. Differing in this important property, it may also differ in other respects, hence it does not follow that the bud should have roots like the embryo. Moreover, the leaf is not an individual, it is only such when united with the buds, and these at first contain only cellular tissue, extremely few spiral vessels. Such buds, when united together, form Mirbel's *Phyllophore.*

We shall allow Gaudichaud to continue.

"According to the old theories, the vascular system of the second individual is formed by a division of the vessels of the first. Hence the vascular system of the second individual is composed of a portion of that of the first. But if the vascular organization of the second individual is more compound than that of the first, the vascular system of the second cannot be formed from the vascular system of the first. If it be granted that all the vessels of the embryo pass into the primordial leaf, the latter should always possess the organization of the embryo only. But this theory is, I think, now properly rejected. According to the theory propounded to you on the 12th of July (by Mirbel), the vessels of the primordial leaf must emanate from the inner periphery of the embryo. We are here met by the same difficulties. In fact, what becomes of this theory, when it is proved to you by a large number of facts that, as a rule, the primordial leaf is more highly organized than the embryonal leaf, and that e. g. the fourth and fifth leaf almost always contain more vessels than the three or four first leaves; moreover, when we show by the same facts, not only that the cotyledonary leaf does not send vessels to the primordial leaf, but also, that in many cases it does not receive any from above, and it then has only an ephemeral existence. In this case the first leaf ceases to exist, because it is not strengthened, and to a certain extent vitalised by the second leaf. Is not this an evident proof of the individual vitality of the phyton?"

Mirbel maintains, if I am correct, that all the vessels of a Palm-stem are not only derived from the internal periphery of the embryo, but also, that wherever leaves arise, new vessels are developed, and thus that they appear at the rings, internally, at the periphery of the stems. From observations which I have made upon this point, I believe that Mirbel is incorrect; I do not find bundles of woody or vascular tissue arising from the rings within the stem, but they all appear to arise from the base of

the stem, and then traverse it in its entire length. Near the periphery the vascular bundles are so crowded that it is difficult to separate them and ascertain their course.

Gaudichaud continues: "We shall naturally apply this principle to the growth of the stem, leaves, fruit, &c., and also extend it to the flowers and other deciduous parts of plants. We would also apply it to the stem of *Vellosia*, which, as it derives scarcely anything from the leaves which exist at the ends of the branches, always remains very thin, for the simple reason that the vessels of the roots of the leaves which should produce the increased thickness of the stem, become applied immediately after their formation to the external part of the bark (*à l'extérieur du périxyle*), and thus descend as roots (*à l'état de racines*), along the twigs, the branches, and leaves, to the ground. The primordial leaf (that first formed after the embryo), undoubtedly obtains life and nutriment, but nothing further, from the embryo; the primordial leaf also imparts vitality and its principal nutriment to the second leaf, and the same occurs with the second leaf in regard to the third, &c."

Gaudichaud always writes in this aphoristic style, which becomes more remarkable from his separating the sentences from each other, and commencing a new line.

Again, he says (l. c. p. 610): "In fact, since it is found by observation, that the embryo, this small isolated being, consists originally of cellular tissue only, and that this cellular tissue produces the vessels by its physiological action; that the vessels commence in the internodes of the stem (*mérithale tigillaire*), then appear in the petiolary and the laminary merithals of the leaf; that they are perfectly formed, or at least may be traced in these regions (*dans les parties mérithalliennes*), before they appear in the *papilla* of the rootlet (*mammelon radiculaire*), we are led by analogy to consider that the same must also be the case with the organization of other individuals, of whatever kind they may be, which are produced by plants. This fact I repeat is an important one, and worthy of conside-

ration. I have several times recurred to it, and shall again recur to it, because I believe that it is the key to vegetable organography; because it comprises a theory of the regions (or members) (mérithalles), which I defend; and because it supersedes (*infirme*) all other theories." The basis of his system is principally contained in these words.

Gaudichaud's whole theory rests upon the perfect identity of the buds and the embryo, and the formation of roots or root-like parts in the former as in the latter, when the branch grows. This explains the increase in thickness, which is always a difficulty, especially in the Monocotyledons, and in the cauloma of Palms. It has already been stated above, that the resemblance of the embryo and the buds is not so great as Gaudichaud thinks. Roots growing downwards in the stem are attributed to buds from analogy only, and this is imperfect. Although Mirbel explains the increase of the stem of Palms by the origin of new vessels from the interior of the circumference of the stem, yet the accurate explanation of the entire process is accompanied with great difficulties, independently of the fact that this origin of the vessels cannot be found on accurate examination. But the difficulties vanish if we admit the occurrence of lateral growth, which appears probable at first sight. In my Lectures on Botany (Part II, Berlin, 1845, p. 309), I have shown that the stem of the Date-palm in its early stage, much resembles a bulb, which also at first increases in thickness, and then ascends in the form of a stem; I have, moreover there (p. 237) detailed observations, which show that in the stem of the Dicotyledons, a layer, sometimes thick, sometimes thin, applies itself; this, however, especially indicating lateral growth. Thus the roots of the buds do not pass far down the stem. It is extremely probable that a little cellular tissue may grow downwards from the buds into the stem, but it is doubtful whether vessels descend from the buds into the stem, they certainly do not pass down far in this manner (see my Lectures, &c.,

p. 265.) Mirbel and Gaudichaud pay altogether too little attention to the relative growth and position of the vessels as regards each other. The pertinacious man, as evidenced in his life, will hardly sacrifice any of his theory to controversy; but if it should ultimately tire even the impartial critic, this ought never to go so far as to cause the theory to be rejected without examination.

Schleiden is the most violent of the botanists mentioned at the commencement. As soon as he meets with an opposite opinion, he rejects it immediately, and so positively, as not to admit the correctness of a single assertion in it. The author of such opinions fares still worse; everything of his ceases to be good. By this means, with few exceptions, he has excited all botanical writers against him, and caused many of his own theories to be rejected by others. This should not prevent the acknowledgment of what is good and excellent in him. When we see the straightforward and positive Gaudichaud, we expect a pertinacious adherence to his opinions, but from Liebig's amiable aspect we should not anticipate so severe a man, nor should we suspect, of the quiet Schleiden, that he could trample upon all who differ from him. The first edition of Schleiden's 'Principles of Scientific Botany' was not incorrectly called a libel, in France; this reproach would be unjustly made to the second, on the whole, although in parts the same violence is manifest, and probably expresses his feeling. After its dedication to Humboldt, which all who know Humboldt must admire, the following passage immediately follows, in the preface: "It is an infinitely difficult task, again, to throw off the accessory means of education and to retain education alone, to apply the stifled power independently to objects which have been spontaneously selected. On the large scale this is most strikingly seen in the laughable prejudice for Latino-philological erudition, and the mediæval monkish book-wisdom, which makes all true living progress in our education appear distorted and crippled as an inherited dyscrasy; and just where it appears in its

greatest absurdity, in the Natural sciences, still disturbs the fresh springs of life." Had this been said one hundred years or more ago, it might have been regarded as an expression made at an appropriate time, but it now comes much too late. We must now rather thank those men who, like Humboldt, appreciate the advantage of still cultivating the taste for the dead languages and philological erudition. Humboldt has done this in very many of his writings, very recently in his 'Cosmos,' in a manner which, as we may hope, and must wish, will exert its influence upon an age which is too fond of what is superficial and easy, beyond which it has no desire to proceed. I shall allude here to the effect upon the mind which the wonderful force and simplicity of the dead languages exert, when we regard the impression which they produce only, without referring to the dilution which they always suffer by translation into modern languages. This is foreign to my present purpose. But in the Natural sciences their use is really not absurd, it is much to be recommended in descriptive Natural History, and hitherto has always been retained.

In these languages all European nations understand each other; the plants and animals described by us, Germans, are again recognised from Lisbon to Moscow. Schleiden speaks of the absurdity of species-trifling; but here again, in his peculiar style, he says too much, because the first point is to ascertain what is spoken of, and the determination of species must serve as the alphabet of science; and it then leads us to the answer to one of the most important questions in Botany, viz. what is a species, what a variety, and how the latter are produced? It is, perhaps, most proper that papers which dispense with this, as it were, mechanical method of illustrating objects, should be wholly written in the mother tongue; but it would be well if so much Latin were learned as to cause those manuals which make use of an aphoristic style of description, especially in the Natural sciences, to be understood in every foreign country. The English,

French, and Italians, even at present, are but little acquainted with our labours in the Natural sciences. We, with whom it is part of the education of youth to learn the languages of these nations, more readily become acquainted with the labours of other nations than they do with ours, because our language is much too difficult to be learned by these nations. Hitherto the Russians, in their writings on these sciences, have generally made use of Latin, French, and German; but if they were to begin to write in their own languages, and simultaneously to make great progress in the sciences, we must then either remain in ignorance of their works or learn their language. But Schleiden condemns learning from books, and in his opinion it is of no consequence whether we are acquainted with what has been observed by foreigners or not. He says, in the same preface, "True formative knowledge, that which expands the nobler powers of the human mind, can at the most be acquired in and with the assistance of books, but never from books. Learning from books is the secret and unsuspected source from which the disingenuousness and tendency to dissimulation is first nourished, and which poisons the present age: accustoms us from youth upwards neither to say, to think, or to do anything of ourselves, but merely to fill our meagre and sterile minds with ideas which have been borrowed and handed down from other sources, so as to palm off this abundance as healthy knowledge." He frequently repeats that he has striven to be peculiar and original. In the same preface he says, "I had endeavoured at once, and without any regard to what had already been done, but furnished with all the expedients at our command in the present day, to rediscover the whole science from the direct investigation of nature; thus my work acquired an originality, which, independently of its correctness, always possesses something more attractive than the matter when arranged in an historical and philological form." The author somewhat deceives himself. Where there is a noise, there flock boys and

idlers. He is far less original in his views than Thouars, Turpin, Agardh, Nees von Essenbeck, or Oken, and in description, Gaudichaud is far more vigorous and distinct. As regards his accuracy, this cannot be so easily and readily decided upon, as to exert any striking influence upon the judgment of the reader. Thus, e. g. in the first edition of his book, he follows the theory of the French botanists on the stem, which he certainly defines with more minuteness; and in the treating of the stem of the Palm, he criticises what I have said upon the subject, but without supporting his remarks by any original observations. Original writers are certainly not those who have produced most benefit to science, whilst on the other hand they have frequently retarded its progress, and I should not consider it as any recommendation, were any one to assert that Schleiden was original in his botanical remarks. On the whole, he recommends the critical method, in fact, considers it as the only correct one; but we cannot possibly conceive criticism without some preceding system; in fact, it is quite opposed to peculiarity and originality. It is highly valuable, and we should be grateful to the author's ingenuity if he allowed his criticisms to be decided and severe, but free from such extravagancies, which impair rather than increase the effect they produce. The observations of any writer upon natural history, who only describes what he has seen, are very valuable; but it would be impossible to re-institute a science from the study of nature alone. In making investigations we must know what to observe, and this must be acquired from instruction, and finally from books. Without these means we should merely make discoveries which had long been known. Had it not been learned from books, we should not have been aware that iodine colours starch blue. I was deprived of this resource in my earlier researches, and it has since proved of much service in science. It is too great an exaggeration, nay, it is even false, to assert that books cherish a disingenuousness and tendency to dissimulation which

poison our whole existence. We might with more truth accuse social life altogether, which no doubt frequently renders dissimulation necessary to prevent one being thrown upon the street (obliged to beg).

The author, whilst combating dogmatism in his 'Methodological Elements' (p. 23), passes the following incorrect judgment upon Endlicher and Unger's 'Principles of Botany' (Vienna, 1843). "This false plan is carried out to its utmost extent in the recent work of Endlicher and Unger, and its appearance under the protection of such names can only be seriously regretted. It appears to me that independently of many of the details being objectionable, to which we shall allude hereafter, the authors in writing their book in a rigidly scholastic style, at the present day, have committed a great mistake. From beginning to end, it contains mere explanations of names arranged systematically, and what renders them especially useless, is that the authors have rarely taken the trouble to name examples. Anatomy, physiology, and the history of development, which alone should constitute the peculiar value and true foundation of the details, are very meagre and unimportant, the figures, which are appended at the end, are neither formally nor essentially brought into connexion with the details which are deducible from them only." All knowledge in the natural sciences depends upon definitions, for every fact is comprehended as a definite conception. Merely because the perception of an object or occurrence is repeated, does it become absorbed as manifold, in the unity of the idea, and in this form, we become acquainted with it. In all sciences, and especially in natural history, we must commence with definitions. We must first obtain a definite idea of a part of an organic body; the external form and the connexion with other parts are the first and the most important points to be regarded, for by them we recognise the part; the internal structure, the anatomy, certainly must be known, but it is entirely a subordinate matter. Then follows the doctrine of development, for I must first know

what is developed, and from what this is derived; and the physiological examination of the species follows last. Now I confess that I am unacquainted with any manual of botany which, with aphoristic brevity, fulfils its design so admirably, as the 'Principles of Botany' of Endlicher and Unger. My disagreement with the authors in a few, in fact, in many of their theories, is nothing to the point, for, in so extensive a field, it is impossible always to meet with accuracy. Schleiden finds fault, e. g. with the distinction which the authors make between a conical and a discoid receptacle, when speaking of the floral receptacle, and puts a variety of questions, which in my opinion may be easily answered. The discoid receptacle is furnished beneath the ovary with an annular ridge, which is absent in the conical receptacle, and if I understand the authors correctly, they regard this as an indication of another internode of the stem which commences there. Thus they have explained the presence of the various parts situated beneath the ovary, for by explanation we signify the illustration of the essential connexion of phenomena. But I doubt whether an appendage does not always exist beneath the ovary, indicating the origin of another internode.

Schleiden's theory of the internodes of the stem, mérithalles, as they are called by the French in their usual manner, by a barbarous term derived from the Greek and in opposition to all analogy, is old. The place where a leaf and a bud exist, was called a node, and this was regarded as the commencement of an internode. In the Grasses, each node is evidently the commencement of an internode; in the Palms, internodes are closely crowded and somewhat less easily recognised; the nodes and the internodes are also distinguishable in the Labiatæ, the Caryophyllaceæ, &c., which have opposite leaves, whilst in plants with alternate leaves, they run into each other. If we consider the term node to denote the articulation, we might say with Endlicher and Unger, that in the conical receptacle, there is no node situated above the stamens, until we come to the ovary, whilst in the discoid receptacle, one does exist.

"The peculiarity of the inductive and modern method," says Schleiden (p. 25), "consists in our first completely abstracting ourselves from all hypothesis, not premising any principle, but starting immediately from our direct consciousness, from individual facts, endeavouring purely and completely to isolate these, arranging them according to their essential affinity, ascertaining from them alone laws to which they are subject, and which are essential to their existence, and thus tracing them back, until we arrive at those ultimate ideas and laws, with which all further deduction ceases to be possible." This may be very true; but it is least applicable when the doctrine of development, anatomy, and physiology are assumed as the foundation of the investigation. The second book, the doctrine of cells in plants, begins as follows (p. 197): "Cells can only be formed in a liquid which contains sugar, dextrine, and mucilage (cytoblastema). It takes place in two ways:—1st. The mucilaginous parts become condensed into a more or less roundish body, the cell-nucleus (cytoblast) and at their whole surface convert part of the liquid into gelatine, or comparatively insoluble substance; a closed gelatinous vesicle is formed, the external liquid penetrates into and distends this, so that the mucilaginous body becomes unattached on one side, and remains adherent to the other side of the internal walls; it then forms a new layer on its free side, and is thus inclosed in a duplicature of the wall, or it remains free, and is then usually dissolved and disappears. During the gradual distension of the vesicle, the gelatine of the wall usually becomes converted into cellular matter, and the formation of the cell (cellula) is completed. 2d. The entire contents of the cell become divided into two or more parts, and from each a delicate gelatinous membrane is immediately formed; in this manner several cells are simultaneously developed, which then completely fill the cell in which they were formed."

Upon how much that is uncertain is this based! In his explanation, the author himself directly says, "We are far from clear as to the liquid from which the cells

are formed." This is so certain, that the author commences with "It appears." It is moreover uncertain, and is doubted by many, myself among the number, whether a cytoblast is formed before the surrounding membrane; we have never seen it. Although we may find granules, and subsequently cells, in a clear liquid, it does not follow that the former are formed from the latter, moreover, the young cells under these circumstances are frequently empty; sometimes certainly they contain several nuclei. Moreover, it is hypothetical and cannot be seen, that the nucleus of the cell converts part of the liquid into gelatine; that the external liquid permeates the gelatinous vesicle and distends it, is also hypothetical; and, lastly, it is no less hypothetical that the gelatine of the wall becomes converted into cellular matter, and that in this manner the cells are perfected. It is by no means my intention to assert, that these facts are false; I merely wish to say, that we must not commence with these statements—with what is doubtful and uncertain.

I have several times reminded the reader that the cells of the Algæ cannot be regarded as analogues by which the development of cells in the Phanerogamia can be explained. The cells of the Algæ are rather to be compared to the joints of the stem in the Phanerogamia, than with the individual cells of which the stem is composed. The cells of the Algæ are placed in a long tube, and hence were called utriculi, and, in fact, utriculi matricales by Roth. Moreover, the remarkable phenomena which are perceptible in several of the cells of the Algæ, as, e. g. in *Spirogyra*, *Stellulina*, &c., appear to characterise them as peculiar organs. The author remarks, in passing (p. 205): "To guard against false views I must observe here, that the theory of crystallization brought forward by Link, according to which crystals are formed by the confluence of small globules, depends upon imperfect observation." I never thought of saying anything of the kind. When a recent precipitate, as e. g. of carbonate of lime, is quickly placed under the microscope, we observe

nothing but globules, and what proves them to be in a fluid state, is that they are frequently seen to run into one another. The crystal is then suddenly formed; in the above instance, it is a rhombohedron or crystal of Arragonite, according to the temperature. Schleiden has not seen this, and is unacquainted with my little work, 'On the Formation of Solid Bodies,' Berlin, 1841. My friends H. and G. Rose and Poggendorf have seen it. But further: "At first it is natural, that if we desire to observe the formation of crystals, precipitation should not be selected for the purpose, which chemists consider to belong to the so-called irregular form of crystallization, but that the observations should be made at first upon simple crystals whilst separating from concentrated liquids. In this way we observe in each case, as e. g. with nitres, ammonio-chloride of platinum, and most beautifully and readily with the ammonio-chloride of zinc, &c., that the nuclear crystal suddenly springs up, not at any given moment, in the liquid which was previously perfectly clear, and which remains so, and then whilst apparently at perfect rest, is seen gradually to increase in almost imperceptible starts by external deposition." If some chemists consider precipitation as only irregular crystallization, they have done wrong. The above means of making the observations are totally impracticable. If the concentrated solution be allowed to evaporate slowly, the formation of the crystals can only be observed with great difficulty; if it be allowed to cool suddenly, the crystals are formed so suddenly and in such numbers, that individual crystals are difficult to trace. Precipitates which crystallize slowly are the best to examine, as e. g. carbonate of lime, very little of which must be placed under the microscope. In precipitates which crystallize rapidly, as sulphate of lime, the first stage of globules cannot always be perceived, as the crystallization ensues too rapidly; sometimes, however, for this very reason, the phenomenon is seen with surprising distinctness." Further: "If, however, two liquids which yield a single precipitate be mixed

under the microscope, at the instant of their coming into contact, the sudden formation of a membrane, which separates the two liquids, is seen to occur. On minute examination, this membrane is seen to consist of crystals, some of which can be perceived with perfect distinctness, some are seen to be crystals when magnified more strongly, others only when the very highest magnifying powers are used, until lastly the smallest appear only as points, even with the very highest powers. If the liquids are not disturbed, some of the crystals which are formed gradually enlarge on both sides in the liquid; but if the liquids be mixed, a large number of the crystals are instantly redissolved, others continue to increase in size, and fresh crystalline nuclei are suddenly formed in spots where the liquid was perfectly clear." These observations are upon the whole correct; the so-called membrane is a wall of turbid liquid. As long as it appears like a membrane, it is not composed of crystals, but these are soon formed, and it is then composed of them. A similar turbid wall is also seen when the freezing of water is observed with the microscope. See Poggendorff's Annal., vol. 64 (1845), p. 479. Lastly, "After having made many observations and these with great care, I have arrived at the general conclusion, that every inorganic substance, when passing undisturbed into the solid state, immediately assumes a crystalline form; most of the so-called pulverulent precipitates consist of crystals, and the comparatively minute size of others prevents our giving any opinion upon their form." This is certainly the common opinion. But Ehrenberg was the first to show that many fossils consist of globules arranged in rows, and therefore are not composed of crystals, and if the drop of liquid containing the precipitate of carbonate of lime, under the microscope, dries up too quickly, a quantity of powder remains between the rhombohedra, and this entirely consists of small globules. The pulverulent condition of matter therefore, which, I believe, Weiss is almost the only one to admit as a distinct state, cannot be rejected. That crystals are

not at once formed in the liquid, but that a nucleus is first suddenly formed from a liquid, which subsequently increases in size, my observations upon precipitates have shown distinctly.

The author's remarks (p. 53 et seq.) upon the production of the various forms occurring in nature are upon the whole correct and to the purpose. The form either excludes the mother-liquid, i. e. the formative fluid, during its production, or it incloses it. The first is the case in inorganic, and the latter in organic bodies. I should not say, that the crystal during its formation excludes the formative fluid, for the entire globule, or the entire aggregation of globules, in the above experiments is transformed into the crystal. Moreover, this consideration appears to contradict the author's own opinion upon crystallization, according to which the crystal is at once formed in the liquid, and during its increase merely withdraws particles from the formative liquid. But it is certainly of great importance that organic bodies should be formed within an envelope, where external agencies are directed towards the centre of the formative liquid. When the author says: "We thus characterise the idea, organism, as the relation of the figure or form to the inclosed mother-liquid, and life as the reciprocal action exerted between the mother-liquid and the form," he must, on a little reflection, understand how very unsatisfactory are these characteristics. It was, therefore, with satisfaction that I read the author's remarks (p. 64 et seq.) upon Minerals, Plants, and Animals. They contain—if he will not take it unkindly— a poetical effusion, which if it does not distort the facts, forms an agreeable embellishment to the subject.

The treatise on the Microscope (p. 82 et seq.) may be strongly recommended to those who make use of this instrument, although I find the following passage at the end of it (p. 105): "It is considered that little more is required to make a microscopic observation than a good

instrument and an object; the eye has then only to be kept above the eyepiece for the observer to be *au fait*. Link, in the preface to his Anatomical Plates, expresses this thoroughly false view as follows: 'I have generally intrusted the observations entirely to my draughtsman, M. Schmidt, and thus the unprejudiced condition of the observer, who is unacquainted with botanical theories, vouches for the accuracy of the drawings.' The result of this perversion is, that Link's phytotomical plates, notwithstanding his celebrated name, are so useless, that the beginner, at least, must be strongly warned in learning from them, to avoid his being confused by representations which are entirely false. Link might as well have asked a child, or a congenitally-blind person who had just been operated upon, the apparent distance of the moon, and from their freedom from prejudice, have expected the best judgment, just as if in our early years of childhood we commence learning to see with our unaided eyes," &c. I must subjoin here the preface to my Anatomico-botanical Plates (Pt. i, 1837): "The anatomy of the human body only first began to make the great advances in which it now rejoices, when philosophers began to have the appearances delineated by skilful artists. I followed this course as far as I was able. For philosophers are seldom good draughtsmen, and even when they do understand the art, they have no time for its exercise. Hence it very frequently happens that they draw what they have never seen, or what they fancy they have seen under the misguidance of some theory. This is especially the case when the objects can only be seen under the microscope. The most proper person for this purpose is a skilful artist who is unacquainted with anatomical science, and who must not be told what he is to see. A young artist, C. H. Schmidt, who is a flower-painter, has for seven years drawn for me the internal structures of plants, as seen under the microscope. After he had become accustomed to the microscope, I told him that he must only draw what he saw, and always unhesitatingly contradict

me, if he thought differently from me. He did not interest himself in theories, not even in mine. I have presented some figures selected from a large number, which appear to me very accurately and carefully drawn, and shall continue to do so if the undertaking should receive support." I therefore by no means leave the observation to the draughtsman, but only the delineation; I correct him, but do not at once desire compliance, as with a young and dim-sighted artist, but contradiction. I confess that I had in my mind the Plates upon the Circulating System of Plants, and especially Meyen's illustration of the network of the so-called vital vessels in the leaves of *Alisma plantago*. The brief preface to the second half of the Anatomico-botanical Plates concludes with the following words: "But we learn to see, both with the eyes given to us by nature, and with those formed by art." From that time to the present (January 1846), M. Schmidt works with me five days every week in the morning, except during my autumnal tour, and does not draw anything which I have not carefully observed, and my eyes, thank God! are as good as ever. I educated my draughtsman for microscopic delineation, and at the end of seven years he was so far advanced, that I could reason with him; now after sixteen years he is still more so. How can any one be thought so foolish as to have drawings made under his own superintendence without pointing out their object. I beg M. Schleiden not to consider every one a fool but himself.

I must, however, apologize to the reader for having become prolix on matters relating to myself. But something more upon a purely scientific subject. "That property of the cell has already been mentioned," says the author, in the chapter upon "The Life of the Cell," p. 273, "in virtue of which it transmits fluids. It is a perfectly superfluous and clumsy hypothesis, in the explanation of this point, to have recourse to the existence of minute invisible pores; the membrane and liquid here stand in the same relation to each other, as

salt and the water by which it is dissolved. Just as in this case both salt and water are contained in every differential of magnitude (sit venia verbo), so is the cellular matter and the water in that of the membrane; with this difference, that the membrane is never rendered fluid by the water, because the latter merely dissolves a definite minute quantity, and then does not take up more water until the portion first taken up has been removed." Now, where do the aqueous particles exist in the membrane? They cannot exist anywhere but in its interstices, however minute these may be, and however minute the particles of the membrane may be, between which the aqueous particles penetrate. Undoubtedly such interstices, which we call invisible pores, must exist, unless we admit an infinite penetration of the water and the membrane. Independently of the fact that such penetration cannot be perceived, nor even imagined, the water and membrane would then form an indivisible substance. The penetration would also be mere groundless hypothesis. Salt, when in solution, certainly exists only in the interstices of the water; soluble bodies force carbonic acid from the pores of water, because they take its place themselves. Our system of physics must be altogether modified, if we are to deny the existence of invisible pores. Physio-philosophy is alone capable of affording an explanation of this, because, according to its theorems, all forms of matter are originally the same, and the differences depend upon an increase or a diminution of the cohesive attraction of one for the other. Still it would be difficult to find in it an explanation, where membrane and water only are concerned, without admitting the existence of such pores. Are we, then, who are accustomed to work with the microscope, to pretend that we can see everything? Thus there are different gases, none of which are visible to us, and in which we must admit the existence of large interspaces, for the explanation of the phenomena which are exhibited when they are mixed with each other or with aqueous vapour. That these pores are not disseminated

empty spaces, is readily understood; but they are, in most cases, filled with some subtile matters, as air, heat, &c. The membrane of organic bodies allows fluids to permeate it; in endosmosis this is probably effected by electricity. In the living body, these pores appear to open and close—an effect of the vital force, which in many other cases manifests itself to us by contraction and expansion.

Schleiden completely follows Fries in his philosophical views, and has written a pamphlet against Hegel and Schelling, in which he states that he does not attack their system, but merely endeavours to show their ignorance of natural science. The followers of these two philosophers might find much to censure in it, as, in my opinion, would the followers of Fries also, in his illustration and application of the philosophy of Fries. I consider myself as rather belonging to the latter; but this is not the place to discuss the matter. The author does not mention Oken, who certainly deserves consideration. However, I will not give rise to a dispute, which under the present circumstances could not prove of any advantage to science.

Scientific disputes are usually beneficial to the progress of science. They not only augment the interest of science itself by producing novelty in its monotonous course, but they also possess the advantage of causing the disputant to develope the grounds upon which his opinion is based, more fully, for the sake of more clearly illustrating it and convincing his opponent. Whether he succeed in the latter or not, must be left undecided by the disputant; but so much is certain, that if this is not immediately or very shortly the case, one or the other ultimately acquires conviction. The advantage which would result from the development of the grounds for or against any view vanishes, when mere contradiction—i. e. rejection without a reason—is made use of. It produces the least advantage to science when the dispute is carried on with a truly original rudeness, as is generally done by Schleiden.

It is very wrong to repudiate physio-philosophy as paying no regard to facts, but proceeding with purely mental conceptions. Such is not the case. Oken, Nees v. Esenbeck, and Wilbrand, like all other physio-philosophers, assume facts as their basis; and only err, in my opinion, in comprising them under ideas of too wide an extent. Thus, under the idea of polarity, they include so many heterogeneous phenomena, that the definition and application of the idea becomes too arbitrary. In general, polarity signifies an antithesis in different directions. This occurs very frequently in nature, but so generally, that recourse to it not only becomes tiresome, but even superfluous, and withdraws us from more important and exact investigations. More accurate and strict definition of the ideas is requisite, and this again necessitates more minute and rigid determination of the facts. The opponents of physio-philosophy have erred in this respect also. Thus the idea of a cell, as now generally understood, cannot be mistaken; but when we find how the embryo-sac, the cells of the pith and bark, spiral vessels and the joints of the Algæ are so comprised in this term, that what applies to one is considered as holding good as regards the others, there is risk of falling into the most serious errors. The greatest injury effected by physio-philosophy, has arisen from its not only rejecting mechanical philosophy, but even holding it in contempt. Hence the fundamental theories of physics, the theories of motion, have been so neglected in courses of instruction, that we have had to censure the want of acquaintance with them above, even in the opponents of physio-philosophy themselves.

INTERNAL STRUCTURE OF PLANTS.

In no department of physiological botany, if we except the formation of the embryo, has so much been done during the last few years, as on the formation and deve-

lopment of cells. The investigations exhibit a depth of research, which commences with the very earliest origin of the plant, and in this respect they are very valuable. First, Mohl, to whom we are indebted for most of our knowledge on this point, has published:

Remarks on the Structure of the Vegetable Cell, in the *Botanische Zeitung*. Edited by H. VON MOHL and L. VON SCHLECHTENDAL. Berlin, 1844, p. 15 et seq., and p. 273 et seq.—He was led to these researches by Hartig's investigations upon the structure of cells, and his assumption of their possessing a more internal membrane which lines their interior, and which he denominated a Ptychode. "If we examine a first year's shoot of a tree, or the stem of an annual plant, which, before the completion of its growth, has been immersed in spirit and kept in it for some time, we find in all those cells and vessels, the secondary layers of which have not yet attained their full development, an inner membrane, which is remarkably distinct from the other membranes of the cell. This membrane forms a perfectly closed, cell-like, thin-walled vesicle, which in the fresh plant is closely applied to the inner wall of the cell, and therefore escapes observation; whilst in specimens which have been preserved in spirit, it is contracted, and more or less detached from the wall of the cell." He calls this cell-like vesicle the primordial utricle, and found it in a number of Dicotyledonous plants, as, e. g, in *Sambucus ebulus*, *Ficus carica*, *Pinus sylvestris*, *Asclepias Syriaca*, *Hoya carnosa*, *Euphorbia Canariensis*, *Caput Medusæ*, &c. In the Monocotyledons, he detected it in the apex of the stem and of the root. But this utricle can be seen by a shorter method than that of keeping the portions of the plants for a long time in spirit. In general, the preparation need only be exposed to the action of nitric or hydrochloric acid for a few minutes; if the acid be then neutralized with ammonia, and the preparation be coloured by iodine, the primordial utricle is

seen just as beautifully as by the long preservation in spirit. As the primordial utricle exists in all young cells, the author thinks that it contributes to the formation and growth of the cells; for, he adds, we can only conceive cell-growth to occur in two ways, either by division of the older cells by the formation of a septum, or the formation of cells within other cells. He believes that in the cambium-layer of *Pinus sylvestris, Sambucus ebulus, Asclepias Syriaca,* and *Euphorbia Caput Medusæ,* he has seen two primordial utricles prior to the appearance of a septum between them, which, therefore, confirms the latter method of formation. However, he is by no means free from doubt on this point. What we have just asserted entirely agrees with Schleiden's theory, except that Schleiden believes the cell-membrane to be formed from the nucleus. Mohl, on the other hand, considers that the cell-membrane always surrounds the nucleus. Moreover, according to Schleiden, the cell-membrane first formed constitutes also the later one—the external membrane of the cell; whilst, according to Mohl, the membrane of the primordial utricle becomes the external membrane. Hermann Karsten mentions having seen the primordial utricle in his memoir, 'De celle Vitali;' but he confounded it with the internal layers of the membrane of the cell. The author names several excellent examples of the various cell-membranes, and concludes, in opposition to Hartig's opinion, as follows:—"The above remarks show that a positive decision of the question, whether the cells are invested with a special membrane or not, is accompanied with no little difficulty, since optical illusion (Mohl means a luminous appearance) and a slight modification in the substance of the innermost layer of the cell, and this may also occur in the intermediate layers, may readily lead to the belief that such a membrane has been found. Hartig obtained his proof from the cells of *Taxus baccata,* in which Mohl long since showed that there existed a third layer. We must

gratefully acknowledge that Mohl has now first taught us the true structure of the membrane of the cell; that the wall of the cells and vessels is composed of a primary, external, imperforate membrane, and a secondary one which is usually perforated with apertures. It constitutes the basis of our knowledge upon this subject. We may add, with Payen, the outer membrane is not coloured yellow by iodine, whilst the internal lining is so. Mohl further adds, that the internal membrane consists of superimposed layers. This is by no means rare, especially in the solid, cartilaginous, so-called stony cells, several remarkable examples of which have been adduced by the author also in this memoir; but is not found in all, at least has not been positively detected. Why, then, should we admit their existence in parts where they are not visible? How the primordial utricle is converted into a cell having a separate existence, the author does not by any means show; and we shall hereafter allude to the fact, that it not only exists in the young cells, but also in those which have completed their growth, and not unfrequently even in old cells, provided they have not become too solid and cartilaginous. But when Mohl says, that the increase of cells takes place either by the division of the older cells, by means of a newly-formed septum, or by the formation of cells within other cells, a third plan is evidently overlooked—viz. the formation of new cells between the old ones. Mirbel has already shown this in his memoir upon *Marchantia*. It appears to me to be the true manner in which their increase takes place. I have had the anatomy of the bulb of *Amaryllis formosissima* drawn in my Plates (Part I, pl. 1). We there see, in fig. 4, at the base of the leaves, a zone of short, laterally distended cells, with thinner walls than those above and below them. Hence they appear to have been recently formed; moreover, the granules contained within them are not coloured blue by iodine, as the granules in the cells, which are situated

above and below them. The latter cells are large and polygonal, tolerably uniform in diameter, and contain large granules of starch. If we imagine to ourselves these transverse cells extended longitudinally, they would assume the same form as the polygonal cells existing above them. These transverse cells appear to me to be those last formed, and to have sprung up where the large polygonal cells are separated from each other, and have left gaps. That such gaps must be formed during the growth of the parts is unavoidable. As the stem increases in thickness, the woody bundles of the liber become separated from the pith, and the layers of woody tissue grow up between them. These certainly could not force asunder the parts between which they grow, but these latter must separate from each other, by virtue of a distinct and peculiar vital power of expansion, to allow the growth to take place. Physiologists, in giving their attention to matters of little consequence, often overlook others which are of great importance, as has happened in the case of this peculiar property. Mohl has nowhere shown, as he very modestly confesses, that the increase of the cells is produced by the primordial utricles.

In other general respects, the observations upon this utricle, detailed by Mohl, are, as might be expected, minute and accurate. I have not only examined plants which have been long kept in spirits, but also, and much more frequently, such as have been macerated for some time in nitric acid. It is unnecessary to neutralize the nitric acid with carbonate of ammonia, and the section only requires to be washed with water, to obtain the result just as distinctly. Colouring the object with iodine renders it still more distinct, and is, therefore, very important. It is also unnecessary to select parts which have not completed their growth; all that is requisite to obtain the same result is, that they should not have become too hard and dry. I have tried this with many plants; but among them I shall only mention the leaves

of *Allium porrum*, because in the garlics the spherical clear bodies exist, which exhibit an appearance of one cell within another, and have sometimes confirmed observers in the belief that the young cells were contained within the old ones. We shall call them the secondary cells. On making longitudinal sections parallel with, or even perpendicular to, the surface of either the upper green portion or the under colourless part of the leaf, and examining them in a drop of water in the usual way with a sufficient magnifying power, we perceive in the white part the light cells, which appear clear and transparent; in the green part, we see here and there a little of the granulo-cellular matter, which most of the cells contain, and we also find the light, globular, secondary cells. But if the sections are moistened for a few minutes with nitric acid, and then washed with water and coloured with tincture of iodine, the whole is changed. We now see, inside the cells, a sac of a yellowish colour, and almost of the same form as the cells, but more or less irregular, frequently lacerated, more or less detached from the wall of the latter, and also more or less contracted. It is completely filled with the granulo-cellular matter, and when secondary cells are present they are scattered within the sac, more deeply coloured than the sac of the cell, and completely filled with granules. The external membrane of the cell remains transparent, and perfectly uncoloured. But the most remarkable feature exists in the small warty projections on the margin of the sac, which fit into apertures in the external membrane of the cell; between them this membrane appears raised in roundish portions, and sometimes we perceive obscurely-defined laminæ in these tumid spots.

After these experiments, I must express my approval of Hartig's memoir upon the Structure of the Vegetable Cell. The membrane of the utricle is evidently his Ptychode, a membrane which descends into the so-called pores of the external membrane, and is really a distinct membrane; it surrounds the internal contents, but

belongs to the secondary layers as it is coloured yellow by iodine, whilst the outer membrane, Hartig's Eustathe, and the intermediate layer, Hartig's Astathe, are not coloured. Hartig must not be offended at my refusing to adopt these technical terms. They are not only perfectly superfluous, but even retard the progress of science; they form the skins which science must throw off at every moulting period. The inner membrane of the cell, or the membrane of the utricle, belongs, with the spiral vessels, to the secondary formations, and undoubtedly has some relation to the formation of spiral vessels, although not that which Hartig has far too positively asserted. I shall now immediately pass to—

The Life of the Vegetable Cell, together with its Formation, Growth, Development, and Dissolution. By Dr. Theodore Hartig. Berlin, 1844. 4. — This memoir requires very careful analysis, which cannot be given in a few words. We shall only make a few remarks upon it here. In the first section—The Life of the Vegetable Cell, during the period of Cell-formation, the author says, *a*, "Origin of cells.—Cells are only formed in the interior of a parent-cell. They are originally simple Ptychodal cells with fluid contents, the cell-sap. In the course of its development, the Ptychode becomes subdivided into an inner and an outer Ptychodal membrane; in this manner a Ptychodal space is formed, which is distinct from the cavity of the cell. A fluid resembling the laticiferous fluid, the Ptychodal sap, is secreted in this cavity from the sap of the cell. In the Ptychodal sap the new cell-germ is formed; this becomes developed into three different kinds of cells, digestive-, propagating-, and colour-cells. The digestive- (Metacard-) cells effect the further elaboration of the sap of the cell. The propagating- (Epigon-) cells develope a new generation of cells, of three different kinds, in their Ptychodal cavity, in the same manner as the original parent-cell. The colour- (Euchrom-) cells form Euchrome (which includes

Chlorophyll) in their Ptychodal cavity, and starch." Then follow observations in which, as regards the contents of the cells, so far as my own investigations enable me to judge, many of the details are minute and correct. In fact, too minute, for these contents hardly appear to me to deserve the name of cells; the most we could call them would be cell-nuclei, cell-vesicles, or, with the author, nuclear corpuscles. They are always of very different sizes and shapes, never equilateral, even when closely crowded, hence they are not formed by internal expansion; they are never distributed regularly, and often appear to be perfectly solid internally, like granules of starch. The secondary cells, as I have denominated them above, are the most regular; they also contain small cellular granules. The granules of Chlorophyll in succulent and water-plants are of a tolerably regular figure, but they appear solid, and altogether of a very different nature from the cells which surround them externally. The cytoblast appears to me to be a granular mass, which is possibly inclosed by a membrane, but this I will not decide; according to the author, it is a perfectly-developed and not a young cell. He makes the following remarks upon it: "There can scarcely be any doubt that the cell-germ of the cytoblast and of the nuclear corpuscles may, like that of the cavity of the Ptychode, become free and capable of further development; but it is equally as certain that the cell-germ does not originate exclusively from this source, because it is also formed in exactly the same manner as within the cytoblast, in other parts of the cavity of the Ptychode of the cell, where there are no cytoblasts. In fact, I believe that, as a rule, the cytoblast does not produce any propagating cells, but that its function is rather the elaboration and conversion of the sap of the cell into that of the Ptychode." If the author believes the latter to be true, he should not say that the former can scarcely be doubted. On the contrary, it is very doubtful, and has not been proved to occur by any of his observations. In all these investi-

gations it would be very desirable that the objects should be carefully distinguished. What applies to the Algæ cannot necessarily be assumed as holding good in the case of the Phanerogamia, and still less, what is observed in Fungi, as the author has done. His observations upon the cells of the ripe and unripe berries of *Solanum nigrum* are valuable, but this is a distinct subject, and one which may be of importance as regards the ripening of the fruit, and it would have been very desirable for the author to have instituted a minute comparison in this point of view. Again, the title, 'The Life of the Vegetable Cell,' says too much. My friend Hartig knows as much of the life of the cell as I do, i. e. nothing. Life is motion, arising from internal excitation, and we are unacquainted with the movements of the fluids in the cell which produce development.

Schleiden says, in his 'Principles of Scientific Botany,' p. 200: "I believe that even in the youngest condition of the cell, a delicate membrane and a substance which is not colorable by iodine may be distinguished; the former of which completely incloses the cytoblasts. Mohl has apparently (Bot. Zeit., 1844, No. 15 et seq.) misunderstood me, in relying upon an expression which was certainly ill-chosen by me, and by which I intended to illustrate this point, when I first published my discoveries. But as soon as this primary membrane of the cell has become even slightly separated from the cytoblast by its expansion, the whole of its inner surface is very frequently found covered with a delicate coating of semifluid (very often circulating in reticularly-anastomosing currents) mucilage, which is sometimes granular, sometimes perfectly homogeneous and pellucid, but may always be rendered visible either by nitric acid, alcohol, or iodine; this is Mohl's primordial utricle." The granulo-cellular mass, called the cytoblast, certainly always appears surrounded by a delicate membrane. At first this mass appears compact, but subsequently it becomes divided, and then the motion of the small granules begins to be visible. In the cells

of the pith of the recently-developed twigs of the willow (e. g.) this mass assumes a tolerably compact form; in twigs of a year's growth it is found diffused, and has formed dotted cells. Now it appears to me, that this membrane becomes applied whilst in a delicate state to the wall of the cell, and in certain parts penetrates more deeply through the secondary deposit, until it reaches the outermost membrane, and in this manner the apparent holes or pits are produced. The prominences seen on the utricle after it has been detached by nitric acid, and which fit into depressions in the membrane of the cell, and the elevations between them, appear to prove this to be the case. The nitric acid probably only acts by contracting the parts and rendering them visible. The membrane inclosing the granular contents, when detached from the walls of the cell, is only rendered of a pale yellow colour by iodine, and at first is not at all coloured by it. From these considerations, it appears clear to me that this membrane is applied to the outer membrane of the cells, and that it is again detached from it by the action of nitric acid, but for this very reason it cannot be a primordial utricle.

UNGER'S *Memoir* in the 'Botanisch. Zeit.,' 1844, s. 498 et seq., *upon the Growth of Internodes anatomically considered*, properly belongs here. The author counted the internodial cells existing in *Campelia Zanonia*, and then compared the number with their length and breadth, whence he arrived at the conclusion, that the enlargement of the internodes is the result of the continuous growth of the new elementary parts, and also that the enlargement of the internodes of the axis arises from both the addition of new elementary parts and the increase of those already existing. He then goes further, and proposes the question of how, and in what manner, the addition of new elementary organs (cells) takes place in the growth of the internodes. He examined a longitudinal section which passed through several internodes, and then found that the formation of

new parts occurs in the internodes themselves and not in the nodes. He moreover says, "If we carefully examine cellular tissue, in which new formations are in progress, we find what is very remarkable, that all the cells are not furnished with walls of equal thickness, but, on the contrary, that some of them are delicately constructed, whilst others are scarcely perceptible. From this we may conclude that, in all probability, the latter are of a later formation, and hardly entertain a doubt that any observer will admit both the fact and the conclusion derived from it." The next question was, whether the separating wall was single or double. To determine this point, the author selected some young hairs which were in the earliest stage of development, from the recently-formed leaves of *Syringa vulgaris*. He endeavoured, by the action of chemical re-agents, to produce a condensation and contraction of the finely granular contents, so as to allow of the more perfect examination of the walls. Dilute mineral acids answered tolerably, but the result was best obtained by first subjecting them to the action of caustic potash, and subsequently iodine. Even then the separating walls always remain simple. Hence the author thinks that this forms the commencement of a subdivision into more cells, and therefore calls this form of cell-growth merismatic, but he is too hasty in his conclusions on this subject. As Unger expressed his dissent from Schleiden's theory of cell-formation, the discoverer of the spermatozoa (or whatever else they may be called) in the anthers of the Mosses, and the ciliary motions of the spores of the Algæ, &c., receives the following reprimand in the 'Principles of Scientific Bot.,' p. 210: "Transverse and longitudinal sections, and a mere glance through a microscope, be this ever so good, are certainly not sufficient now-a-days for making phytotomic investigations."

In the first part of Schleiden and Nägeli's 'Zeitschrift für wissenschaftliche Botanik' (Zürich, 1844), there is a *Memoir*, by Nägeli, *upon the Nuclei of Cells, Cell-forma-*

tion, and Cell-development, wherein Schleiden's theory of Phanerogamia is brought forward. In the second part (1845), we find an appendix, entitled, Definition (*Begriff*) of a cell. The author, after making some remarks upon Schleiden's definition, says: "The idea of a cell signifies that a portion of the organic matters becomes individualised, invested with a membrane, by means of which it is put in relation externally with the absorption and exhalation of matters, whilst internally it undergoes chemical and plastic changes." The commencement is perfectly correct; the idea of a cell signifies that a portion of the organic matters becomes individualised, so that the solid parts form externally an envelope, within which, in part at least, matters exist in a fluid or even in a gaseous state. Whether in all cells a solid body is first formed, does not appertain to the idea, nor has this been proved to be the case by observation. The nucleus of the cell, as it appears to me and to others, is an irregular accumulation of granules or vesicles, and seems more like the mere commencement of a formation, than a primitive formation itself, which here, as in almost every other case originates in a liquid. The author says, with perfect truth, the idea of an organism combines two important forces—that by which it lives, and that by which it propagates itself. But when it is added, that both of these depend upon its being composed of cells, this dependence certainly is not apparent. If it is proved that the motion of Browne's molecules depends upon an internal influence, they are alive, whatever may be their internal structure. The organism requires a reciprocal action of the parts upon each other as organs, which is certainly most easily produced by the movement of fluids within them; but it by no means follows, it is not proved, nay, it is opposed to experience, that it is entirely composed of cells. If it were stated that it is produced from cells, my reply would be, that this is very probable, but nothing more.

In the search for definition of a plant and of the vegetable kingdom, much dependence is placed upon the

absence of nitrogen in the membrane of the cells of plants, and also upon the presence of nitrogen in the animal kingdom. But supposing that nitrogen were to occur in the membrane of several vegetable cells, would the plants for this reason, cease to be plants? Boussingault has shown that a large quantity of nitrogen exists in plants, but where, has not been positively determined. It is reversing the proper method to commence with chemistry in the study of natural history: and this, first, because chemical analysis is the most difficult; secondly, because its resources are inexhaustible, and cannot be regarded in the same light as the latter; and lastly, because it affords us no insight into the intimate structure of organic bodies, as is proved by isomeric substances. The membrane of plants is isomeric with starch, as Payen has shown, and yet the two are very different from each other.

Investigations upon the Growth of Cells. By Dr. SCHAFFNER of Herstein. Flora, 1845, 481.—"If we may be allowed," says the author, "to deduce conclusions from the investigations which have been detailed, the following cells increase by primary cell-formation. 1. The cambium cells (which are subsequently developed into prosenchyma and vascular cells). 2. The cells of the liber, which do not differ materially in their earliest stage from those of the cambium, but form a distinct system. 3. Part of the cells of the parenchyma, to which the cells of the leaf (excepting those of the cotyledons), and the cells of the parenchyma of the fruit of the apple and the plum provisionally belong, i. e. should the absence of secondary cells in them be confirmed." This is of no importance, the point is whether the so-called secondary cells are really such, i. e. are formed from the parent-cell. "By the formation of secondary cells, the remaining cells of the parenchyma increase, as seen, e. g. in the cells of the pith and of the bark, &c." (???) "Increase of cells by division certainly does not occur in Phanerogamous plants." (?)

In an appendix upon the laticiferous vessels, he advises us not to read upon the subject at all, because most of what is stated upon it involves much contradiction; he quotes Bischoff and Schleiden. He has not mentioned my researches. In the first part of my Lectures on Botany, he would have found much upon this subject; and also many figures in the Plates to the first part of my Anatomy of Plants.

Researches on the earliest Modifications of Organic Matter and the Formation of Cells. By M. Coste. Comptes rendus, 1845, 2, 911, 1396.—This memoir principally treats of the animal cell, and tends more by reasoning than experiments to show that the theory of the production of cells by the nucleus is not based upon satisfactory investigations.

The preceding experiments upon the manner in which new cells are formed, induced me to make some extended observations myself. Thus, when our object is to become acquainted with the manner in which cells are reproduced in the Phanerogamia, without confusing the phenomenon with others not appertaining to it, the method of proceeding used by Unger is the best. With this view I caused some bulbs of *Allium cepa* to grow in a hyacinth glass filled with water, and made marks upon the roots which had grown out, with Indian ink, one close to the bulb, another close to the conical apex, and a third midway between the two former. In a few days the roots had grown very considerably, the conical apex not so, as far as was distinguishable, the base had grown but little; the portion between the apex and the middle had grown most. The latter portion was again divided in the middle, and it was found that the part nearest to the apex had again grown very considerably, whilst that next the middle had grown but little. On making a longitudinal section from the mark at the apex to near the upper mark, treating it with nitric acid, and then iodine, a great many short cells were seen near the apex, these were found gradually to

increase in length towards the upper part, and finally became very long. But the cells at the circumference of the root were longer than those in the centre. In all of them the inner membrane was separated from the walls of the cells, and was contracted around the granular contents, which were of a dark brown colour. The sac thus formed assumed the shape of the surrounding cells, the walls of which did not appear at all coloured by the iodine. Each cell contained the globular sac, which I denominated the secondary cell above; it was also of a brown colour, and filled with a granular mass. It was always situated in the longer sac, but in different cells sometimes at the ends, sometimes in the centre, sometimes near the centre. Thus, where the growth was most active, short cells appeared to have been formed, which then became elongated and had completed their growth. I could not satisfactorily perceive any division of cells. I had made similar marks to those upon the roots, on the young leaves which sprouted out from the same bulb; one near the bulb, another just beneath the apex, and a third midway between the two other marks. That nearest the apex remained unchanged; the apex of the leaf, just as the apex of the root, did not grow; that portion between the mark on the apex and the middle had increased but little, just the reverse of what occurred in the roots, in which this was the part which had grown most, whilst that part of the leaf near the base had increased very considerably, whilst in the roots, on the contrary, it had grown but little. A longitudinal section of a marked leaf was then made parallel with its surface, from the base of the leaf at the root upwards, and treated as before. In this case, as had previously been found in that of the root, short but not broader cells were found at the base of the leaf near the root, where the growth commenced, and these increased in length upwards, towards the middle of the leaf. The formation of these short cells and their elongation evidently produces the increase in size of the leaf, as I have already remarked in my 'Lectures on Botany,' (p. 83,) and have

had figured in my Plates (part I, pl. i, fig. 4*b*). There was no appearance of the formation of one cell (secondary cell) from another (parent-cell), and the inner sac remained unaltered, still forming an inner sac, and certainly not becoming external. This is what ensues during the growth of the cells in the parts of the Phanerogamia. The phenomena which occur in the embryo-sac, or in the cells of the Algæ, which, as the remarkable phenomenon seen in the cells of the *Spirogyra* show, perform different functions from the cells of the Phanerogamia, do not belong here, and no conclusion can be drawn from these so-called cells as regards the cell properly so called. The apices of the roots and leaves which do not grow, consist of very short cells, all of which contain a nucleus of considerable size; this, however, as in the other cells of the leaf and root, never becomes developed into a distinct cell.

On the Penetration of the Cuticle into the Stomata. By H. v. Mohl. Bot. Zeit., 1845, p. 1, and Ann. and Mag. of Nat. History, vol. xv, p. 217.—The different statements which have been made upon this subject induced the author to institute some investigations upon it. For this purpose he adopted the method of soaking the sections of the leaves for examination in tincture of iodine, washing them with water, and then submitting them to the action of sulphuric acid. The latter not only heightens the yellow tint of the cuticle when coloured by iodine, but it has especially this advantage, that the cells of the epidermis of most plants are disintegrated, with the production of a blue colour, or entirely dissolved, according to the strength of the acid employed, and the cutiele can then be very readily distinguished and separated from them. The general result obtained from these investigations was, that, as asserted by Payen, a direct prolongation of the cuticle penetrates into the stomata, and runs down between the cells bordering the orifice to the air-cavity, in the form of a tube very highly com-

pressed on both sides. In the opinion of the author, no doubt can be entertained, after careful examination, that this tube is not closed either at the entrance into the stomata, or lower down, between the cells of the orifice. When it has arrived at the inner termination of the stomatic aperture, this tube dilates into a smaller or larger funnel-shaped expansion, which clothes the inferior surface of the epidermis so far as this bounds the air-cavity externally. This funnel-shaped expansion presents some varieties in different plants, which the author details. Thus the cuticle either lines the walls of the air-cavity only, without penetrating into the intercellular passages, or it penetrates into some, or even all, of those passages which are in connexion with the air-cavity. Lastly, the author comments upon the question of the cuticle being a peculiar membrane, different from the epidermis. He believes that it is not so, but that its peculiarity arises from a change in the substance of the external layers of the epidermal cells themselves. Were I to pass hastily over this paper, as the author says is my custom (although not very politely), I should say that the point is not how the cuticle is formed, but whether it is composed of the outer walls of the epidermal cells, and as this has not been shown to be the case, it must be considered as a peculiar membrane until it is so. At all events, the question remains *in statu quo*. But, as in all questions relating to the formation of organic bodies, we must look forward for a complete elucidation of this point, to a clearer insight than has yet existed.

Investigations upon the Cellular Structures which fill up Vessels. By an anonymous Author. Botan. Zeit., 1845, p. 225.—The author first shows that these bodies consist of true cells, or, as he expresses it, that they are phenomena analogous to the ordinary simple cells of plants. These cells are not generally formed while the plant is young; in first year's shoots of *Vitis vinifera* and *Sambucus nigra*, as also in the stems of *Cucurbita pepo*,

the vessels were empty in summer; towards the end of October and at the beginning of November they only contained a small number of cellules adhering to the walls of the vessels; but a month later he found them copiously furnished with both large and small cells. In a fourth year's branch of *Robinia pseudacacia*, the most external annual zone was in a condition similar to that of a first year's shoot of the same plant; the three inner ones were completely filled with cells. As regards their being adherent, he makes the remarkable observation, that the small cells are always attached to the side of the vessel when it is surrounded by cells of woody tissue or the parenchyma of the medullary rays, but never to a wall which is bounded by an adjacent vessel. Moreover he observed that one of these cells always lies in front of the dot of a vessel, which corresponds with the dot of the adjacent external cell. He also believes he has observed that the membrane of the utricle has some relation with the primary membrane (which belongs to the external cell and the vessel, and which closes the two dotted canals), and that in its earliest stage it is an expansion of this primary membrane into the cavity of the vessel. Hence the formation of the inner cell depends upon the activity and development of an external adjacent cell. This is most distinctly seen when preparations of these vessels in *Vitis vinifera* and *Sambucus nigra* are treated with caustic potash. To avoid unnecessary circumlocution, he adds, he cannot avoid assigning names to the objects, especially to distinguish the old cell from the utricular sac, which he denominates the *thylle*, these two composing one compound organ. Considerations upon the formation and development of these and other cells follow. The investigations of the author deserve the greatest attention and careful repetition, for the purpose of either confirming or correcting these observations upon a remarkable phenomenon.

We have received accurate and comparative experiments

on the chemical peculiarities of the vegetable cell, first from Payen, he having previously made his excellent observations on Starch. The whole of these investigations were published in 1842, in his 'Mémoires sur les Développemens des Végétaux.' He first instituted his experiments upon the cellular tissue, which consists of little more than membrane; this was taken from very young parts, e. g. the ovule of the almond, pear, and apple tree, and of *Helianthus annuus;* the delicate membranes formed upon the coagulated drops of fluid which exude from the sections of the vessels of the cucumber, also upon the pith of young shoots of *Sambucus nigra*, cotton-wool after a first and second purification, and the spongioles of roots, and the pith of *Aeschynomene paludosa* (rice-paper). All these substances were repeatedly treated with dilute hydrochloric acid and ammonia, washed with water before each repetition of the process, and lastly exhausted with alcohol and ether. They were then strongly dried, powdered as far as possible, and then burnt with oxide of copper. He found, as the result of the elementary analysis, the composition C^{24} H^{22} O^{2}, which is isomeric with starch. He then gives a simple, direct experiment, by which cellular membrane may be recognised under the microscope. A small section, e. g. of rice-paper, is placed under the microscope in a drop of water; one or two drops of an aqueous solution of iodine are then added, which produce a pale-yellow colour; and lastly, a drop of concentrated sulphuric acid. The membrane is then first coloured blue, and is finally wholly dissolved, so that only yellow traces of the matters which were contained in the membrane remain. A better method than this one of Payen's, is to place the section for microscopic examination in a drop of water, then to add a drop of nitric or hydrochloric acid; to let the whole remain for about two minutes, then to wash the section with water, and to colour it with tincture of iodine. The membrane itself now appears perfectly colourless; sometimes it is slightly bluish here and there, from a portion of starch which is dissolved, and all the foreign matters are rendered deep

yellow, so that they are readily distinguishable from the membrane. The experiments upon the leaves of *Allium porrum* and the roots of *Allium cepa*, which have been already detailed, were made by this method. It must be remembered that the starch-granules are here dissolved; hence, if it be required to observe them, no acid must be used. If this experiment be reversed, and the section be first examined with tincture of iodine, the starch is easily recognised; but no nitric acid must be added, because it dissolves the iodised substances, leaving the membrane, which cannot now, at least very readily, be recognised and sketched. But by this method the membranes of the utricles, the contents of which are dissolved, are distinctly seen within the cells. Caustic potash and caustic soda also remove the contents of the membranes, and leave the latter, although in an indistinct state. But I must return to Payen's investigations. He next examined, by elementary analysis, the following structures, after having exhausted them with several solvent media. The leaves of Endive and *Ailanthus glandulosa*, the internal cellular tissue of *Agave Americana*, the spiral vessels of *Musa Sapientum*, the radicles of maize; portions which had resisted the digestive process in animals, the albuminous tissue of maize and corn, the albumen of *Phytelephas*, and the kernels of the date; the hairs of the seeds of the Virginian poplar, the vegetable membranes of which the nest of the wasp is constructed; the heart-wood of the oak, the wood of the Coniferæ, also *Conferva rivularis* and *oscillatoria*, the membrane of *Agaricus edulis*, probably *Ag. campestris* L. He also makes use of the name *Scariola*, as well as "*Chicorée endivie.*" How can any chemical investigations be of use, if the object which has been examined is not definitely stated? Then follow investigations upon the substances existing in the cells which also contain nitrogen. I have quoted these details here for the purpose of introducing a memoir by *Fromberg, on Cellulose*, given in the 'Scheikundigen Onderzoekingen,' 2 D. s. 36, and which is extracted into the 'Journ. f. praktische

Chemie,' 32, Bd. s. 198. He subjected *Cetraria Islandica* and *Agaricus albus* to elementary analysis, and his results agree tolerably well with those of Payen. He then makes the following remark: "I am also satisfied as to the perfect accuracy of his experiments, yet I cannot deny that I am astonished, first, at not finding it stated anywhere that he previously determined the amount of ash, except in his first memoir (Annal. des Sciences Natur., 2 sér. t. ii, p. 27), since even if he had not found any ash present, he ought to have mentioned it; moreover, since none of the substances mentioned by myself as having been analysed were perfectly free from the so-called incrusting matter, and since the results of Payen lead to the same conclusion, which is explained by the intimacy with which these substances permeate the primary cellular tissue; and again, since silica, which is so generally diffused throughout the vegetable kingdom, would very probably have entered into the composition of these matters, it does not appear possible that the vegetable structures subjected to examination could have been perfectly free from silica." This suggestion is quite correct. Payen gives the amount of ash contained in the vegetable structures when not yet separated from the matters deposited upon the cellulose. We thus find that 10·80 p. c. of silica are stated to exist in the leaves of Endive, but none in the leaves of the same plant when exhausted of everything but the cellulose. This is very improbable, for the amount of silica in the leaves of the Graminaceæ, before purification, is stated to be 12·25; but I find no analysis given of the leaves after purification. But in this case the amount of silica existing in the cellulose must be very large, for the incinerated leaf is so completely converted into silica, that all its parts can be accurately distinguished under the microscope; a remarkable phenomenon, and one which still requires careful investigation, because it is opposed to what we know regarding cellulose.

In the same 'Scheikundige Onderzoekingen,' l. c. p. 62, 'Journal f. Prakt. Chemie,' l. c. p. 204, we have an

Analysis of the Seeds of Phytelephas, Ruiz et Pavon (*Elephantusia* Willd.),* by BAUMHAUER. He gives his results in the following words: "Our results show distinctly that the perisperm of *Phytelephas* does not, as Payen states, consist of pure cellulose, contaminated with albumen, two nitrogenous substances, silica, two fatty bodies, and salts; but that, in addition to these matters, of which the albumen, the two nitrogenous substances, and the two fats are in extremely small quantity, an additional deposited substance occurs, which differs but very slightly in its per centage composition from cellulose."

We shall take this opportunity of subjoining the observations which have been made upon Starch during this period. First:—

Description and Figures of some remarkable Forms of Granules of Starch in the Root of Sarsaparilla, and in the Rhizome of Hedychium Gardnerianum. By G. BISCHOFF, Bot. Zeit., 1844, p. 385. The granules in the former root are very often of a hemispherical or half-ellipsoidal form, moreover they [illegible] by their [illegible] there are four or more gran[illegible] connected together in [illegible] manner. These various forms are accurately described and figured. The author compares them to the combinations presented by many kinds of pollen granules, they might also be compared with a three-valved leguminous capsule. Several othe[illegible] might be added. I have met with a form in which [illegible] occupied the centre, and the other [illegible] around this, that the whole figure [illegible] tapetalous flower. The author remarks that the concentric lamination was not perce[illegible] in daylight, but it was distinctly so by subdued lamp-light. The author also found potato-starch to consist of a combination of two granules. The starch existing in the rhizomes of the

* One botanist considers that the alteration of the word *Phytelephas* into *Elephantusia* would be a very unnecessary change. But *Phytelephas* signifies a vegetable elephant, and such a zoophyte is something too terrible.

Scitamineæ is singular enough. The granules are cylindrical, and either curved or bent at an angle; they are sometimes club-shaped, or of various other forms, some of which resemble a pileate Fungus, and in consequence of their being contracted between the rings, they distinctly exhibit their laminated or tunicated structure, each main-ring again exhibiting a larger or smaller number of exceedingly delicate, parallel, curved, transverse markings. The larger segments undoubtedly denote the separate granules of the composite structure, and each of these is again finely laminated.

On the Starch of Gloriosa Superba, L. By JULIUS MÜNTER. Bot. Zeit., 1845, p. 193.—The form of the granules of starch which exist in the rhizome of this plant, is sometimes that of a perfect sphere or ellipse; but by far the larger number of granules are bounded by one or more plane surfaces, which sometimes meet at an acute, sometimes at a right angle. If we divide an egg, says the author, through its middle, at right angles to its long axis, we obtain two kettledrum-shaped halves, these accurately represent, on a large scale, the appearance frequently exhibited by the starch of *Gloriosa*. Other pieces resemble that form which we should obtain on dividing an egg anywhere parallel to its longitudinal axis; other forms again represent sections of a sphere, i. e. pieces which are bounded by two plane surfaces intersecting each other at an angle of 120° and one spherical surface. Sometimes we find three plane and one spherical surface; and lastly, we have also pure stereometric forms, pentahedra, hexahedra, and octahedra. Occasionally the granules are of an indefinite form, which does not admit of description. *Maranta bicolor* Kerr, and *Jatropha manihot*, also exhibit pentahedral granules of starch. The author brings these forward as a proof that even an organic compound may assume a crystalline form, and from this consideration he applies to them the term glandules. It is then found that these glandules become disintegrated when removed from the cell and placed in water, upon

the object holder, which is not usually the case, for in other plants the granules retain their connexion. The author then passes to the investigation of how these granules of starch are formed and developed. We might at first imagine, says he, that as in crystallization, the amylaceous plasma (the analogue of the saline solution) is deposited upon the little globules which first separate, and that in this manner, by the continuation of deposition upon their outer surface, larger granules are formed. We might add to the author's explanation that the granules are formed around a nucleus, as is usually considered to be the case from the manner in which crystals are formed. According to the author's view, the twin granules of the nucleus of the one individual must lie close beside the nucleus of the other individual, and nearly in that plane in which both are connected, or near the parchment of the kettledrum, if the above comparison is retained. This is not the case, for the nucleus is situated in the bottom of the kettledrum, at the end of the elliptical or spheroidal section (this is also shown by the figures given by Bischoff.) The author then proceeds to the question whether the pressure of the cell inclosing them might not produce an angular form. But this is not the case, for the granules have an angular form, even when they do not completely fill the cells. It is evident, says the author, from what we have stated, that pressure cannot be the cause of the formation of the gland-like collection of starch. From all this, he adds, all that remains is the prospect of a peculiar formative process in the vegetable kingdom. Regarding the vegetable cell, we know with perfect certainty that the concentric appearances, as seen e. g. in the stony tissue, as it is called, of the pear, &c. arise solely from the centripetal formation of layers. But nothing is opposed to the view that the layers of the granules of starch also are formed by centripetal, i. e. internal deposition; on the other hand, this hypothesis is supported by the fact that the nucleus, as it is called, of Fritzsche, or the central cavity of Schleiden, contains much water, and is, as it

were, gelatinous. For as soon as sulphuric acid is added to the granules of starch, under the microscope, and it begins to remove the water from the inner layers, a bubble of air appears in the place of the nucleus; the same occurs when the granule of starch is heated; in fact, even when fresh starch is dried at the ordinary temperature of the air. The latter phenomenon, which was not observed by either Schleiden or Fritzsche, thus also explains the formation of the fissure near the nucleus. But if, as appears from these observations to be the case, the nucleus and the layers nearest to it, contain more water than the outer ones, i. e. if they are softer and less consolidated than the outer layers, we might assume with tolerable certainty that the central layers which surround the nucleus are the youngest, and the peripheral ones the oldest. Now, if this hypothesis be retained as the most probable, there is no difficulty in explaining the spot where the nucleus should be found. Accordingly as the layers happen to be thick or thin, the nucleus must be situated more or less excentrically, in fact it must be excentric in the large globules. For as soon as the centripetal formation of the layers was uniform in all parts of the inner surface, a condition would occur, which would prevent any further development, because the walls being everywhere of equal thickness, the transmission of new nutritive matter would be prevented, whilst this condition would never occur if one part of the granule were thinner than the rest. When the walls of the cells are thicker, other means come into play in facilitating the access of nutriment, viz. pore-canals. The author moreover adds: "We must rest satisfied for the present, with the conclusion which has been arrived at negatively, that a process similar to that of cell-formation must be admitted to occur in the case of the granules of starch, the nature of which must form an object of future investigation." It is very pleasing to find that the author has differed from the ordinary explanations of the formation of starch. I quite agree in his opinion, that the granules of starch are formed from

without inwards, and that this is produced by a peculiar process of formation, which certainly resembles the process of cell-formation, but is not always perfectly regular. I should attribute the eccentricity of the layers around nucleus, solely to this irregular formation. The granule of starch apparently absorbs moisture on all sides, and then developes the layers internally. A similar internal formation is also the cause of the regular separation of the granules in the root of *Sarsaparilla*, which then finally passes into the external crystalline form of the granules in the tubers of *Gloriosa superba*, as was first discovered by the author. All the granules existing in the same tuber, even those close together, are not of the same form; some are more rounded externally, some are rounded on the sides, bounded on the others by two planes, because originally they separated from each other at that part, others are bounded on all sides by plane surfaces, like the central grain in the compound form, presented by the granules in the root of *Sarsaparilla*. I should always ascribe these crystalline forms to the internal separation of granules, to which view I was led by the granules of starch in the bulb of *Ornithogalum (Myogalum) nutans*. But the author will publish his own investigations upon that point. He then adds some remarks upon Schleiden's observations on this subject in his 'Systematic Botany.' The amorphous granules of the seeds of *Coriandrum minus* arise from desiccation; this is also the case with the cup-shaped granules of starch in the rhizome of *Iris pallida*. Schleiden, in opposition to Meyen, incorrectly denies the occurrence of discoidal granules in the Cannaceæ; for in *Canna variabilis* for example, we find only such. The arrow-root of commerce presents considerable differences; the author details them. Most of the commercial article is obtained from *Tacca pinnatifida*; the same statement applies to sago. He could not detect any cup-shaped granules in *Rad.* (*stolones*) *Iwarancusæ*, such as Schleiden states to occur. I look forward to the continuation of the author's accurate and valuable investigations.

Observations on the Formation of Starch. By C. MULLER; Bot. Zeit., 45, 833.—They were instituted upon *Chara crinita*, and, according to the author, they exhibit the following points: it is the cytoblasts which are transformed into starch, and this only occurs in cells which are mature.

Note upon the Phenomena produced by the Transmission of Polarized Light through Starch. By M. BIOT. Compt. rend., 1844, vol. i, p. 795.—In his previous experiments the author examined the granules of starch by means of two prisms, one of which was placed above the other, and crossing it at right angles; on the present occasion he changed the apparatus by so placing a plate of mica between the two prisms, that the median line between the two axes formed an angle of 45° with the principal sections of the prisms. The mass of the granule is then seen illuminated with bright colours, the tints of which vary with every change of position, and with the direction in which the luminous rays are transmitted; so that, as in a picture, all the curves of the outline, all the undulations of the surface, all the peculiarities of the structure, and the slightest accidental alterations become sensible. Probably under some circumstances this means may prove of the utmost value; but in the present case, considering the great and accidental varieties in the structure of the granules in starch, it is perhaps of minor importance.

We shall now pass from cells to vessels. In the 'Annual Report,' for 1841, I made some observations upon the work of C. H. Schultz, on Cyclosis in plants. The author has replied to them in a book which we shall allude to presently, viz.: 'Discovery of the True Nutritive Process of Plants,' Berlin, 1844. He there says, with regard to my remarks, p. 54: "There are two main points to be considered: first, whether I have correctly denominated the vessels of the liber, vessels of the vital fluid (*lebenssaftgefässe*); and, secondly, whether the currents of fluid in *Commelina cœlestis* consist of a circula-

tion (rotation) of the granules without any trace of anastomosis, as in *Vallisneria.*" He has distorted my statement, and I must therefore briefly repeat my remarks. Schultz was the first to detect the motion of the fluids in the so-called proper vessels (*vasa propria*), he also first gave good illustrations of these vessels. But to carry out his hypothesis regarding Cyclosis, he has attributed these vessels, which he denominates vessels of the vital fluid (laticiferous vessels), to many plants in which they do not exist. They are said to occur in the bark of many trees, as the birch, but I only find vessels of the liber in it, and no one has seen them in it, even the author himself only represents their transverse not their longitudinal section, thus we are ignorant as to whether he has really seen them or not. This is most striking in *Commelina cœlestis*, in the stem of which plant, near the spiral vessels, ramified laticiferous vessels are said to pass out and spread over the adjacent cells. He has given a figure of this. But I find, besides the spiral vessels, merely rows of parenchymatous cells, in which granules circulate as in the cells of *Vallisneria*; next to them, are more rows of broad cells, in which currents of fluid are visible, but they are certainly not inclosed in vessels. Therefore there is no trace of ramified vessels. The result is, that the motion of the fluid in the so-called laticiferous vessels is the same kind of motion as had been previously found in plants, namely, as the circulation in the cells of plants, discovered by Corti, which was first accurately observed by Meyen in *Vallisneria*, and the currents of fluid which Robert Brown first observed in the hairs of *Tradescantia*. The motion of the liquid in the articulations of *Chara* is of the same kind. The author makes the following remark among others: "It is to be regretted that the author should have been able to gain so little by the most earnest exertions and sacrifices to solve this problem, that he has rather misunderstood it altogether, and by useless opposition to the evolution of truths, the great importance of which was first recognised abroad, deprived himself the renown of having aided in their

promotion." An example of the incomprehensible arrogance of the author who is bound to a fixed idea. The Academy of Paris certainly awarded him the prize for his Memoir upon the proper vessels, for which no one will censure them, but they declared at the same time, that they do not participate in his views. No academy can test the accuracy of the individual details which are contained in the prize-essays, nor could the Paris academy do so in the present instance.

There is an analysis of the milky juice of *Asclepias Syriaca*, by the same author, in the 'Flora,' 1844, p. 374.

Phytological Studies. By M. le Comte de TRISTAN. 4th Mem. *Researches upon the Laticiferous Reservoirs and Canals,* Ann. des Sc. Nat., 38, t. i, p. 176.—This memoir is directly opposed to Schultz's views. Some parts of plants do not contain any laticiferous vessels, hence they cannot serve for nutrition. On the properties of the latex. Varieties in the laticiferous vessels. It is impossible to condense this memoir into the form of an abstract.

STEM AND ROOT.

On the Dependence of the Increase of Thickness of Dicotyledonous Trees, on the Physiological Activity of the Leaves. By H. MOHL. Bot. Zeit., 1844, p. 89.—According to the theory of Dupetit-Thouars, says the author, the lateral growth of the stem is in connexion with the expansion of the buds, therefore with the formation and development of new leaves; and depends upon the circumstance that the buds, in the same manner as a germinating plant, send out radical fibres which descend between the bark and the stem, and form a new layer of wood; according to another theory, the lateral growth of the stem depends upon the activity of the leaves, because they prepare the nutritive fluid, which is applied to the formation of new woody layers. To decide this point,

the author measured the circumference of some trees, which were about eight years old and in an active state of growth, at various periods from the commencement to the end of the vegetating season, and calculated the mean daily increase in the circumference of the stem for each of these intervals of time. The trees were, *Gymnocladus Canadensis, Gleditschia macracantha, Tilia argentea, Populus Græca, Pavia lutea,* and *Morus alba.* A table of the increments is added. The following details are selected from the author's remarks upon his experiments: On the 22d of June the terminal buds of *Pavia lutea* were already formed, but the lateral growth, instead of ceasing, from the above period to the 22d of August, somewhat increased; it then diminished to a small amount. From the 2d of March to the 22d of June, hence before the development of the terminal buds, the circumference of the stem increased 11·8 millimeters; from the 22d of June to the end of the year 16·2 millimeters; so that by far the greater proportion of the increase occurred during that period in which no leaves were developed. The same was found to be the case, although less strikingly, in *Gleditschia* and *Gymnocladus.* Hence the author draws the conclusion, that these observations are directly opposed to the theory of Petit-Thouars. Valuable as they are in themselves, the adherents of Petit-Thouars will not rest satisfied with them, but will object that the roots of the buds, between the bark and the stem, which cause the lateral expansion of the stem, would be small and delicate at the commencement, but that they increased with the activity of the leaves, and in this manner augmented the thickness of the stem. The author adds, that the circumference of the stem also increased, although to a small extent only, when the buds began to enlarge and expand. Hence he thinks that nutritive matter, prepared the preceding year, is applied to the first expansion of the stem in the spring, without the leaves preparing it. Why not? Although it appears determined by numerous experiments, that the leaves serve for the

preparation of the nutritive fluid, there is at present no ground for limiting this preparation to the influence of the leaves alone, if the observations definitely indicate another mode. Lastly, against Agardh's view, that trees grow principally in length during the first half of the summer, but principally in thickness during the second: which is not in conformity with observation.

On the Growth of Internodes, considered Anatomically. By Professor UNGER. Botan. Zeit., 1844, p. 489.—This memoir has already been spoken of at p. 230. It was necessarily brought forward there in connexion with the origin of new cells by division, a mode of formation which I should confine to the Algæ alone. Here we have to notice the general growth of the parts, of which the author very modestly says, that in one special instance—i. e. *Campelia Zanonia*—it takes place not only by the formation of new cells, but also by the increase of those already formed. This law might, in truth, be extended to all the Phanerogamia at least.

In the 'Comptes rendus,' 1844, t. i, pp. 899 and 972, we have the fourth notes relative to the protest of M. C. Gaudichaud, of which we have already spoken.

Continuation of the Anatomical and Physiological Researches upon some Monocotyledons. By M. MIRBEL. (Second Memoir.) Compt. rend., 1844, ii, 689.—In this memoir the author gives a very accurate description of the stem of *Dracæna Australis* (*Cordyline Australis*), as regards its internal structure, and especially the course of the vascular bundles. He endeavours to prove that the latter arise from the root, and from the inner wall of the stem. He has not only described the stem when perfect, but also when young, and this with great care. I first expressed my views on this subject to the Congress of Italian philosophers at Milan, and they are published in the 'Atti della sesta reunione degli Scienziati Italiani

tenuta in Milano,' Milan, 1845, vol. iv, p. 511; more in detail in the 'Flora,' 1845, p. 272; also in my 'Lectures on Botany,' part ii, Berlin, 1845, p. 309. The Date-palm is the subject there treated of. In germination, the embryo or the cotyledon becomes elongated, as is usual in the Monocotyledons, and splits into a sheath, from the base of which the stem grows upwards and the root downwards. The former, which is surrounded by the sheath, contains within it a small tuberous body, consisting of parenchyma and delicate spiral vessels passing round it; above, it immediately forms a bud, consisting of leaves only, as in the Monocotyledons generally. The leaves acquire considerable length, whilst the stem remains as an almost spherical tube. If it be examined at the end of several years, about six or eight, its section exhibits a nucleus, which is throughout traversed by a plexus of vascular bundles, which interlace in every direction. The nucleus is surrounded by a cortex of parenchyma; at the upper part, beneath the bud, there is also a layer of parenchyma forming a cortex, through which vascular bundles pass from the nucleus to the leaves. Thus the young Palm perfectly resembles a *corm*, which only differs from a true bulb in the absence of the fleshy scales. On making a section of the tall part of the stem of a Date-palm, we find a number of vascular bundles traversing it longitudinally. The nearer they are to the circumference, the closer they are together; and at the very circumference they are most closely crowded, whilst towards the centre they are more scattered, more surrounded with cellular tissue, and they are most scattered at the very centre. On closely examining the woody bundles, we find that they are by no means parallel to each other, but interlace in various ways, forming, however, but very small angles with each other. Hence the stem of a Palm is a longitudinally extended corm.

Neither Mirbel nor Gaudichaud have noticed this bulb-like condition of the young Palm-stem, nor have they

definitely alluded to the fact that the Palm grows at the summit only, and that the vascular bundles arise from the interior solely at that part, and grow towards the leaves. Hence I cannot agree with Gaudichaud's opinion, that the vascular bundles arise from the leaves, although he has often quoted me amongst a singularly-enough selected series of authors who are of his opinion. Neither, on the other hand, can I agree with Mirbel, in considering that vascular bundles arise from the interior of the stem. The growth takes place at the summit only, and there the vascular bundles come out from the interior.

Gaudichaud's "Memoirs against Mirbel," are in the 'Compt. rend.,' 1845, i, 1375, 1436, and 1677, and ii, 99, 201, and 261; the memoir upon the Stem of *Ravenala*, in the same year (ii, 391), must also be referred here.

Dr. v. Martius has written a paper *Upon the Process of Growth in Palms, especially as regards the Course of the Fibres in the Stem*, which was published in the 'Gelehrte Anzeige' of the Royal Academy of Sciences of Bavaria, for February, 1845.—The author communicates his results to the Academy of Sciences at Paris; hence they are given in the 'Compt. rend.,' 1845, i, 1038. Gaudichaud has expressed himself strongly upon and against them (p. 1207). Mirbel also is dissatisfied with them. This was to be expected; he who takes the middle path is repulsed on both sides. The vascular bundles, says the author, originate at the summit of the growing point, in the nucleus of the bud or "*phyllophore*" (according to Mirbel), in the substance of the more recent cellular tissue which is in course of development, and which here forms a peculiar layer, coating the older and subjacent parts like a mantle; the recent ones being always formed externally to, and more or less above, those already developed. This is explained in the subsequent parts of the memoir as follows:—As the young plant, even in its first stage after germination, is furnished

with conical sheathing-leaves which arise from the periphery of the axis, and these, as well as all the subsequently formed leaves, derive their vessels from the axis, the very earliest development of vessels must be peripheral; and this method of succession is preserved, as long as any leaves continue to be formed. Moreover, the upper end of the vascular bundle, says the author, tends towards the base of the leaf, the lower end becomes elongated obliquely downwards in the form of a delicate filament, consisting of parenchyma, but which never extends into the root. The spots from which the vascular bundle arise at the summit of the bud, are organically predetermined: they are there placed with their upper ends converging obliquely towards the centre, and become elongated in both directions—i. e. grow both downwards and upwards. The spot at which the upper end of the vascular bundle passes to the leaf, is situated either on the same side of the stem as that in which the course of the vascular bundle is chiefly included, or opposite the point of origin of the vascular bundle, obliquely as regards the diameter; in which latter case, the vascular bundle traverses the entire stem obliquely. As the summit increases in length and thickness, each vascular bundle crosses another bundle, either in the interior of the stem or nearer to the periphery, at the point where, either ascending almost perpendicularly, or suddenly taking a horizontal direction outwards, it enters into the leaf. These are, undoubtedly, the most valuable remarks which have been made upon this subject, and I am glad to find that they confirm what I have stated previously, though less completely. Still I must confess that I am in doubt regarding the growth of the vascular bundles upwards and downwards. The author's explanation does not contain any proof of the occurrence of this growth in both directions. In my opinion it always occurs upwards, but in the same manner as is seen in the corm at the base of the young stem, except that the bundles cross at smaller angles as the growth of the stem pro-

ceeds. Some of the bundles may occasionally diverge more considerably, as the author and Mirbel agree in stating. I have no doubt that here also new vascular bundles are formed between the old ones, which certainly takes place as in Dicotyledonous trees.

On Gaudichaud's Theory of the Merithals. By Professor Guis. Meneghini. Giornale Encyclop. Italiana, vol. i, p. 17.—This memoir, which was written as early as 1843, at the time of the meeting of the Congress of Philosophers at Lucca, must have contributed much to draw attention to Gaudichaud's system. The author sketched the elements of this system, which consists in the unity of the axial system of the plant with the appendicular system, the plant being regarded as composed of phytons, intermediate forms, so to speak, between the stem and leaf. The author admits this system as established, endeavours to illustrate it by analogy with animals, and considers that it must have the greatest influence upon organography. It would have been more desirable that the author, with the acuteness he possesses, had investigated the whole theory more closely. He would then have seen that the exposition of the system rests upon an arbitrary assumption, which can only produce hypothetical results. That the radicle of Dicotyledonous seeds, of the Grasses and Cyperoideæ, is the future stem, has been known for thirty years; but this is not the case in other Monocotyledons. That all parts of an organic being are originally one, no one can doubt, but that the latter is directly developed into these parts, and that the developed leaves, e. g., do not constitute the entire stem, is evident on the slightest examination. The author states his explanation of Gaudichaud's system to be as follows: The fibres neither ascend nor descend; they are formed in the previously-existing cellular tissue, by a gradual conversion of the cells of the parenchyma; the organization of the fibres is determined by the currents of the nutritive fluid and the descending fluids (sap);

the mechanical action of these, and the materials which they bring with them, contributing to it, &c. But this conversion has not been proved to occur; in all probability it is entirely false, and the currents of a fluid may become suddenly changed; in the germinating cotyledons of the Monocotyledons, when emitting radicles, they pass suddenly upwards into the stem, and downwards into the root. But it is perhaps unfair to criticise the author from an old memoir, as since that time he has proceeded with his investigations, and we have still much to expect from him.

New Researches upon the Development of the Axis and Appendages of Plants. By M. C. NAUDIN. Annal. d. Scienc. naturell., 3 sér. vol. i, p. 162.—These observations are in general accurate and valuable, although they are not new. The leafy parts (appendages), says the author, are the lateral products of an axis, which at first consist of cells only; they also at first consist of cells only, not containing vessels, and the apex of the axis, the centre of a bud, exhibits a tubercle (mammelon) which is in connexion with the pith. The second part of my Select Anatomico-botanical Plates contains many figures which show this more distinctly than the author has done; but so it is, our labours run parallel with those of foreigners, yet we are generally a little before them. But no; the author is actually acquainted with Duchartre, Guillard, and Schleiden, who have investigated this subject. Recently, in the second part of my 'Anatomy of Plants,' the plates contain further illustrations of this subject. What he states of a few Monocotyledons only, viz. that the spots, where the vessels arise, are denoted by a modification of the cellular tissue, applies to most plants; and has also been illustrated in the part of my work alluded to above. The distinction which the author makes between the axis and the foliaceous parts, viz. that the former grows at the extreme point, whilst no addition takes place at the extremities of the latter, is

not perfectly correct, for no addition is in fact made to the very extremity, or external circumference of the axial parts, any more than to the apex and the upper end of the borders of the leaves. The author confounds this with another subject, namely, that the leaf appears and is developed before the petiole; and in support of this view he quotes Morren, who (in opposition to me) has asserted that this does not occur in the aquatic plants, e. g. *Hydrocharis morsus ranæ;* but when the entire plant is examined, the commencement of the leaves is distinctly seen before any trace of the petiole can be distinguished. The author's remarks upon the development of Monocotyledons are very imperfect. He only treats of the bulb of *Narcissus pseudo-narcissus*, and that in a very superficial manner. He might also have seen very strikingly, in the first part of my 'Select Anat.-botan. Plates,' that the vascular bundles are continued from the stem into the root. His idea of distinguishing a spadix from a spike is to the purpose; thus, in most cases, the summit of the bud is covered by leaves, whilst there it grows up naked.

Micrometric Researches upon the Development of the Elementary Parts of the Annual Stems of Dicotyledons. By M. G. HARTING. Ann. d. Sc. Nat., 3 sér. vol. iv, p. 210.—It is difficult to give an extract of this extensive and valuable memoir, without exceeding the limits of a Report like the present. The author only treats of the annual shoots of Dicotyledonous plants. First, of the method and means adopted in his micrometric investigations. Then of the opinion that an annual shoot may be regarded as composed of several individual internodes (mérithals) of different ages, but having the same original structure, so that, by the examination of the various internodes of the same shoot, we may conclude as to the changes undergone by any internode in the course of its growth. The youngest internode of the shoot, it is well known, is the last, and even a superficial examination

shows, that the lower internodes first cease to grow. Investigations upon the growth of the shoot of *Tilia parviflora* follow, arranged in tables; these include: increase of the individual internodes in length; increase of an individual internode at different ages; increase of the pith; multiplication of the cells of the pith; increase of the longitudinal and transverse diameter; of vascular and liber layers; transverse diameter in proportion to the longitudinal; parenchymatous layer of the bark; number of rows of cells, proportion of the diameter of this layer to the diameter of the internode, increase of the cells of this layer in comparison with the increase of the cells of the pith; Schleiden's callenchymatous layer,* i. e. the layer of remarkably long cells, which exists beneath the epidermis in many plants; number of cells in the peripheral layers. We next have similar investigations upon *Humulus Lupulus*, as also upon the nucleus (cytoblast) in the cells of the pith, the corpuscles existing in the layers of the liber, and the growth of a shoot, which had been deprived of its leaves at the apex. Again, investigations upon the shoots of *Aristolochia Sipho, Phytolacca decandra*, and *Sempervirum arborescens.* Then follow the results: 1. The growth of each internode depends upon the formation of new cells, the expansion of the cells, and the thickening of their walls. 2. The multiplication of the cells takes place in three directions: in that of the radius—radial growth; in that of the periphery—peripheral growth; and in that of the axis—longitudinal growth. 3. The radial multiplication only occurs in the buds. 4. This multiplication is produced by means of cross septa, which are formed in the previously existing cells, without the latter becoming subsequently absorbed; the subdivisions thus formed continually become more and more isolated, in consequence of their expanding on all sides. 5. The expansion of the cells in the radial direction is uniform and equal, so that the diameter always

* "A term as elegant as it is superfluous," as Schleiden once said against me on a similar occasion.

retains the same proportion until the formation of wood occurs. 6. The lignifying layers (vascular layers and liber) do not begin to expand in a radial direction until the fibrous cells have begun to acquire thickness; but then with a force which exceeds that with which the pith and the parenchyma of the bark expands. 7. During this period, the cavities of the cells and vessels expand uniformly, and this also still takes place after the thickening of the fibrous cells has commenced. The increased space which the vascular and prosenchymatous layers occupy in the old segments, must be ascribed to this increase in thickness, not therefore to deposition upon the inside of the wall. The author says in a note, that the development of the fruit in the Drupaceæ, and of the albumen in the seeds of some Monocotyledons, shows, that the increased thickness also arises from deposition upon the outside of the wall. Must the expansion necessarily arise then from a thickening of the walls? The interstitial growth of cells and vessels, which undoubtedly takes place in old stems, indicates an expansion without any thickening. 8. The lateral expansion of the cells composing the different layers, usually takes place (at least in the pith, in the parenchyma of the bark and of the epidermis) with the same force in all directions. But this law is liable to exceptions according to the activity of growth. 9. In the stems of those plants in which no central canal is developed (*Tilia* and *Aristolochia*), the cells constituting the pith, the liber, and the parenchyma of the bark, do not multiply peripherally, but only in the direction of the longitudinal axis. The peripheral multiplication is only perceived in the epidermal and callenchymatous layers. 10. In the plants just mentioned, neither the number of the vascular bundles, nor, consequently, that of the vessels increases. The diameter of the latter increases in proportion to the expansion of the vascular layers. 11. In those plants, on the contrary, in which a central canal is developed, the cells of all the layers multiply peripherally, as is also the case with the vessels. This multiplication, in the author's

opinion, causes the absorption of the fluids in the internal cells, and their desiccation, which explains the origin of the inner cavity. 12. When canals containing gum occur in the pith or in the parenchyma of the bark (*Tilia*), they increase but little in diameter during their growth, but they multiply, and when the elongation is completed, they again diminish and become thickened. They already exist at the very earliest period. 13. In those stems in which a central canal is not formed, the increase in breadth depends upon the radial expansion of the cells, excepting in the layers of the callenchyma and the pith. In those stems in which a central canal occurs, the part which the multiplication and expansion of the cells takes in its formation, is variable. 14. This is also the case in the longitudinal growth. 15. The longitudinal multiplication of the cells, as also their expansion, takes place simultaneously at all points of the internode, but in those internodes which are still elongating, the cells of the pith, of the parenchyma, of the bark, and of the epidermis at the apex of the internode, are shorter than those at its base, and the latter again are shorter than those at the apex of the adjacent older internode. When the expansion of the cells at the base has ceased, that of the cells at the apex still proceeds for some time. 16. The smallest cells multiply most, hence the epidermal cells more than those of the parenchyma of the bark, and the latter more than those of the pith, but no definite proportion is observable. 17. Whilst the internode is still very young, the growth takes place principally by the multiplication of the cells only. When the internodes of a plant, after they have acquired their full length, are of slightly different lengths (*Tilia, Humulus*, and *Aristolochia*), the numbers of the cells of the pith and bark, in the younger internodes, form a geometrical progression. Moreover, the younger the internodes are, the less they grow, and when the growth is accelerated with advancing age, it observes a geometrical progression. All this shows that the multiplication of cells takes place in geometrical progression. For

instance, each cell subdivides into two, and each of these again into two more, and so on. As the internodes become older, the growing process becomes still stronger, because the expansion of the cells is then combined with their increase in number. The growth decreases gradually at last, because after the increase in the number of cells formed has ceased, the expansion still continues to some extent. 18. Hence three principal periods may be distinguished in the growth of the annual shoots of Dicotyledons: 1st, that in which the internode still constitutes a part of the bud, and where the increase in the number of cells is only radial; 2dly, that in which the internodes increase both in length and breadth, and this again, *a*, arising from the increase in the number of cells only, or *b*, from simultaneous increase in the number and the expansion of the cells, or lastly *c*, from the expansion of the latter alone; 3dly, that in which the growth in the axial direction has ceased, but where the lateral expansion still continues. 19. Since the longitudinal diameter of the cells in those internodes in which the elongation has ceased remains the same, the various different lengths of the internodes must arise solely from the formation of a larger number of horizontal layers. The author ascribes the differences which are perceptible, when the effect of season upon growth is considered, to this circumstance, sometimes more, sometimes fewer of these layers being developed. 20. In the cells of the pith and of the parenchyma of the bark of the youngest internodes, in which the growth occurs slowly from the multiplication of cells, we find a substance consisting of very small globules. Very few of the cells are furnished with a nucleus (cytoblast) containing a corpuscle. On the other hand, we find in many cells small groups, or simply rings, consisting of these globules. On examining the adjacent older internode, we recognise in a large number of cells, and in the next internode (in which increase in the number and expansion of the cells are simultaneously taking place) in all the cells, perfectly-developed nuclei, which are quite

transparent and provided with their corpuscles. In the transverse section, they appear to be situated in the centre of the cells, whilst in the longitudinal section they are generally seen to be adherent to the wall. They have a flattened form, hence they are detected with difficulty in this aspect. At this period, the granular matter has for the most part disappeared. In the youngest internodes, which have ceased to elongate, and commonly in the next internode also, nuclei still exist in a few of the cells, but they are usually situated upon the lateral walls of the cells. They disappear in the older internodes. 21. During the earliest period of the growth of the stem, neither the production of new cells, nor their expansion, nor the thickening of their walls is dependent upon the presence of the terminal bud, or upon the leaves existing at the end of the articulation.

These excellent investigations might form the basis of the theory of the growth of plants. It is very desirable that similar investigations should be made upon Dicotyledons, the stems of which are subdivided by nodes, and then upon Monocotyledons. The merismatic increase in the number of cells in those plants which the author has examined appears to me proved. There can be no doubt, however, that the septa which are produced must be double; the manner in which they are formed still remains to be determined. In many cases, the growth certainly does not take place according to a geometrical progression; in these an interstitial growth of cells must occur, perhaps in combination with merismatic division.

It is completely decided by all the investigations which have been made, that no formation of cells within cells ever occurs either during the growth, in length or thickness, of vegetable structures, unless we regard merismatic division as such, which would be incorrect. It is by no means my intention to deny the occurrence of this mode of formation in those cases where perfectly new bodies or parts are formed, and the formation of the young plant in the embryo-sac furnishes an instance of the production of cells within cells.

The curvature of stems towards the light will be reported upon in an article in which the general action of light upon plants will be discussed. Dutrochet has made some observations upon the movements of the free points of plants furnished with tendrils, which were spoken of in the previous Annual Report. In the Compt. rend., 1844, ii, 295, there are some observations, by the same author, upon the *Movements of the free Points of twining Plants.* They take place in the same direction as that in which the stem coils itself. Dutrochet connects them with the spiral position of the leaves. In *Solanum Dulcamara* the winding of the stem is sometimes from right to left, sometimes the reverse, and the spiral of the leaves is double. I shall here merely observe on this point, that Mohl has already observed the curvature of both the stem and the tendrils when unsupported. Dutrochet also gives the times in which the turns are completed; but they do not appear to be very constant.

Dutrochet has also made the observation, that in *Epilobium molle* Lam., (*E. parviflorum* Schreb.) *some of the stems grow* directly *into the earth*, like roots. They are thicker than the upright stems, and are furnished with more cortical substance, which Dutrochet ascribes to their descent into the earth, or rather the thickness of the cortical substance arises from the moisture of the earth. (See Compt. rend., 1845, ii, 1186.)

Boucherie reports, that sections of wood prepared by his method (see Annual Report for 1840, pp. 360, 384), kept sound in the earth for three years, whilst other unprepared sections of the same wood entirely rotted in the same place. Compt. rend., 1845, ii, 1153.

As regards WYDLER'S *Morphological Communications*, Bot. Zeit., 1844, 641, 657, 688, 705,—I shall merely remark, that they do not permit of condensation into the form of an abstract. The author there assumes, as his basis, an ingenious method of explanation, which was proposed by Al. Braun (Flora, 1842, 694). But other

expressions should be selected, instead of such indistinct and incorrect ones as uni- and bin-axial, because these are very obscure. In these investigations Wydler has especially endeavoured to explain the remarkable structure of the Solanaceæ. It is so marked that the Natural Order is recognised by it, however the same occurs in other Natural Orders and individual genera, for instance, in the Boraginaceæ, *Phytolacca*, and others.

ROOT. TUBERS. PRICKLES. TENDRILS. GLANDS. STOMATA.

On the Tendency of Roots to strike into the Earth (but really into mercury only). By PAYER. Compt. rend., 1844, i, 993.—In the year 1829, says the author, Pinot remarked that some seeds of *Lathyrus odoratus*, which he had caused to germinate upon mercury, forced their radicles into it. This penetration was afterwards considered to arise merely from the weight of the seed; others did not observe any penetration; and De Candolle regarded the penetration as arising from the stiffness of the root. Payer then made some experiments upon the point, and found that the radicles of *Polygonum Fagopyrum*, although they are stiff and thick enough, remained on the surface, whilst, on the other hand, the much more delicate roots of *Lepidium sativum* penetrated to a considerable depth. Nor does the weight at all contribute to the effect. If the root be withdrawn from the mercury, it does not again penetrate the metal, but it sometimes shoots further, and then the new portion does so. Light and heat increase its power of penetration. The author thinks that the power possessed by the roots of penetrating the earth arises from their power of avoiding light, and seeking for proper soil. This is explaining something that is unknown by something else which is still more unknown. We have only given an extract from the memoir.

The results, only, of a memoir, by Durand, upon *the*

same subject, occur in the Compt. rend., 1845, i, 861. He first historically adduces Pinot's observation, and adds, that Dutrochet ascribes the phenomenon merely to the pressure of the seed; he then speaks of Mulder's investigations, which were made at the same time, and which prove the contrary. He next details the results of his own experiments. When the seeds are fixed above the surface of the mercury, the roots penetrate; but if this is not done, they do so only when the seeds are placed at the side, between the glass and the mercury, or when a layer of the organic matter is deposited from the water, which fixes the young plant. The seeds of *Polygonum Fagopyrum* do not yield any of this matter to the water, hence the roots do not penetrate.

The *Report of the Commission* upon these two memoirs is given in the Compt. rend., 1845, i, 1257. Several points which in the memoirs are not described, but merely alluded to, are more detailed. The reporter, Dutrochet, finds fault with Payer's memoir, because he has not stated whether he fixed the seeds above the mercury, and if so, how this was done. The following remarks are quoted from Durand's memoir: When the seeds of *Polygonum Fagopyrum* are properly fixed during germination, the radicles always penetrate the mercury. If the seeds are placed in water over mercury, without being fixed, they lose as much in weight as the water which they displace weighs; hence they exert less pressure upon the mercury, and therefore cannot penetrate it. If, under these circumstances, they are but slightly covered, they penetrate to a certain extent. As has been already stated, the semi-solid layer of precipitated organic matters fixes the little plant at the surface of the mercury, and replaces the artificial fixation. As the seeds of buck-wheat do not yield any organic matters to the water, we need only add a little of some extract to the water to produce the same result. Some experiments performed by the reporter (Dutrochet) follow next. He says, "we have used several kinds of seeds in these experiments, and especially those

of *Lathyrus odoratus;* but we have never seen that the radicles of these seeds sank more deeply into the mercury than was caused by the pressure which the weight of the seeds exerted upon the radicles, i. e. not more than three millimeters." The Report concludes with the statement that the phenomenon ensues according to known laws; that M. Durand has discovered that the penetration of the radicles into the mercury depends upon the seeds being fixed, and that when this is not the case, the seeds merely penetrate as deeply as the pressure of the seed causes them to do. The Report censures M. Payer for inaccuracy in the description of his experiments; but this would apply still more strongly to the account which the reporter gives of his own experiments, for he makes no mention of the direction of the radicles which penetrated, and yet this is the main point, if it were really the pressure of the seeds which forced the radicle into the mercury. Moreover it will appear easily explicable that the radicles penetrate the mercury, when the seed is fixed, because this is the only remarkable circumstance, and it is strange enough, when Durand's statement is brought forward. If seeds are placed in water over mercury, without being fixed, they lose as much in weight as the water which they displace; thus they exert less pressure upon the mercury, and cannot, therefore, penetrate; since, by fixing them, the weight is entirely removed, and could not, therefore, cause the roots to penetrate, there is nothing else but the force of the onward growth to make the root descend, and it is remarkable that this is not prevented by mercury. The experiment of Payer is very remarkable; he found that the roots of *Lathyris odoratus* descended through several layers of mercury, in an ingenious apparatus arranged for the purpose. It is also remarkable, that when the radicle is withdrawn from the mercury, the portion which had penetrated will not again do so; but the newly-emitted part does, an experiment which excludes all mechanical explanation. The experiments upon the penetration of the radicles of unattached

seeds germinating upon mercury, do not appear to me of any importance.

A remark which has already been frequently made, is repeated by H. Jaubert, in the Compt. rend., 1845, ii, 360, namely, that on that side of a tree on which the branches are strongest, strong roots also exist. He says that he has very frequently found this to be the case in digging up trees in Sologne. It may be well to recall to mind, since these observations correspond with the view, that the nutritive fluids ascend through the spiral and dotted vessels, and as these vessels do not anastomose, they ascend from the root in a straight direction. That the branches, however, assume curves, like the roots, an instance of which is here afforded, appears to be accidental.

Treviranus has described a remarkable *Formation of Tubers, in Sedum amplexicaule.* D. C. Bot. Zeit., 1845, p. 265.—In this plant, says he, the new shoots which are destined for reproduction are much thickened for about the length of an inch at the summit; the leaves at this part are also closely crowded, whilst at the lower part of the shoot they are scattered. About the period of the summer solstice, not only the main stem, which has flowered, dies, but also the lateral shoots, the thickened points of which constitute the above newly-formed living shoots. On examining the latter, we find, completely incased by the dried sheath-like basis of the leaves, a cylindrical mass of cellular tissue, the cells of which contain granules of starch, and the centre of which is occupied by a small ring of fibres and vessels; at its point is a bud consisting of the rudiments of a few leaves, and which is marked with the scars of fallen leaves. It is a tuber, formed by the confluence of closely-crowded leaves. About the middle of August these tubers emit new leaves; these clothe the next year's stem, which terminates in a flower; they are not, however, sheathing like those which surround the tubers, but semi-cylindrical, like the leaves of *Sedum acre, reflexum*, &c.

Pietro Savi on the *Prickles of Amaranthus spinosus.* Giorn. Encicl. Ann., 1, t. i, pp. 17, 310.—The author considers that these prickles are not stipules, as has been thought, but that they are the lowermost, early-developed leaves of an axillary branch. The author's view is perfectly correct; they are situated in the axil of the leaf, low down on the axillary branch, and the main proof consists in their producing tufts of flowers in their axils, which is never the case with stipules. It would be very remarkable were stipules to occur in one species of *Amaranthus* when they are not found in any other, nor in genera related to it.

On the Tendrils of the Cucurbitaceæ. By Attilio Tassi. Giorn. Encicl. A. 1, t. i, p. 2, p. 382.—In opposition to the view that they are stipules. His view is principally founded upon the instance of *Sicyos Buderoa* Hook., the alternate leaves of which are furnished on one side below the base with either one, three or six filaments, three or four only of which in the latter case acquire complete development. The author also alludes to the remarks made upon them at the Italian Scientific Congresses. Auguste St. Hilaire (Mémoir. d. Musée, t. ix, p. 192), whom the author does not mention, is the authority for their being considered as stipules. He quotes an instance of *Elaterium*, and a case of abnormal development of *Cucurbita Pepo*, which had produced stipules instead of tendrils. On this point I have remarked, in my 'Elements of Philosophical Botany,' vol. i, pp. 318-9, "But the so-called stipules in the Gourd were furnished at the point with a small tendril; hence the tendril (as is frequently the case with spines) had produced leaves. This minute tendril appears to be absorbed in *Elaterium*; for the true stipules never arise from one side only of a leaf; they are very rarely stalked, and the stalk when present is never round, as the tendril is almost invariably. The tendril, which is now the subject in question, is also situated close to the branch like the spine, and is also a supernumerary branch."

A. St. Hilaire also treats of this point in his 'Morphologie Végétale,' pp. 185-6, and says, in opposition to the view that the tendril occurs on one side of the leaf, that we find on one side of the leaf a developed stipule, and on the other an abortive one (*Ervum monanthos*), and that it is but a small step from this to its complete absence (?). Moreover, in one of the Cucurbitaceæ in the garden at Paris, he had noticed two tendrils. My 'El. Ph. Bot.' were published as early as 1837, the 'Morphologie' in 1841. M. Tassi must extend his inquiries beyond what is done in Italy.

New Researches upon the Structure of Cistomes. By GUGL. GASPARRINI. Naples, 1844, 4.—The author has previously described a pouch or sac, which is adherent to the stomata internally. He calls these sacs *cistomi*, because they are attached to the stomata (*stomi*). In the present short communication he now describes a canal which arises from the sacs. His investigations were principally made upon *Cactus Peruvianus*, then upon *Ornithogalum nutans*, and *Arum Italicum*. I have also examined *Cactus Peruvianus*, and have seen the sacs but not the canal, which the author himself has only figured in some, not in all. But the epidermis must be strongly boiled with hydrochloric acid to exhibit the sac; hence it appears to be nothing more than the internal membrane of the aerial reservoir, which the thicker epidermis (cuticle) has entered and lined, as has already been remarked by Mohl. Mohl has also found that the epidermis sometimes extends into the cellular tissue, and there forms, as it were, canals. Too strong treatment with acids materially destroys the connexion of the parts, so that the true structure is no longer recognisable; and this is the case in the present instance. I have not been able to find the canal which the author figures from *Ornithogalum nutans*.

C. MÜLLER has communicated to the 'Bot. Zeit.,' 1845, p. 793, *Some observations on the Resinous Exudations*

of the Birches.—Beneath the epidermis a small heap of cells, filled with green matter, is seen, and which is slightly elevated above the surface; it gradually becomes larger, and lacerates the epidermis. More cells then become superimposed upon each other, and form a capitule, with a more or less thick pedicel formed by the lower cells. The outer cells subsequently become wholly converted into a resinous matter, and are surrounded with a dense brittle mass, the pedicel still remaining unaltered. Finally, the granules escape from the epidermis. The dense brittle mass dissolves in alcohol or ether, forming a mucous mass, leaving no trace of any membrane (which however might very easily be concealed in the mucous mass). The author gives the chemical examination of *betuline;* he considers it to be a kind of *stearoptine.*

LEAVES.

Remarks upon the Arrangement of the Leaves in Dicotyledons. By K. S. KUNTH. Bericht d. Akad. d. Wiss. z. Berlin, October 1843.—The position of the leaves coincides with that of the buds, says the author, and when a bud is about to be formed, a portion of the pith is forced through the woody substance towards the surface of the stem. The spot where this takes place depends upon the arrangement of the woody bundles; thus the first year's shoots of the oak are pentagonal, and the leaves are also arranged in five ranks. On endeavouring to connect the leaves by a line in the shortest course, this can only be done in a spiral direction, and from left to right; moreover the spiral line, to be enabled to reach the nearest leaf, must pass over one of the angles of the wood, to arrive at a leaf which belongs to the same series. Five angles are not always present, still five divisions of the wood may always be assumed to exist when the leaves are arranged in this manner. The author next refers the arrangement of the leaves in the shoots of *Castanea vesca*

in two ranks to the five-ranked, remarking that, when we commence with the posterior single odd rank of leaves, the fourth and third are developed, whilst the first, second, and fifth are not formed. In the same manner he reduces the three-ranked arrangement of the leaves of *Alnus glutinosa* to that in five. From the alternate (*scattered*, says the author, which is, however, the opposite of *fascicled*) leaves he comes to the opposite leaves, which he regards like the former, not, as at the same height, lying in a transverse section made perpendicular to the axis, but merely approximated and alternating. He proceeds in the same manner with the verticillate, or whorled leaves. This valuable contribution to the theory of the arrangement of leaves deserves great attention; and it is certainly of importance to consider the angles of the stem in connexion with the arrangement of the leaves. We must connect with this—

On the Arrangement of the Parts of Flowers. By K. S. KUNTH. In the Bericht d. Akad. d. Wissen. Berlin, Feb. 1844.—The whole of the elements of a perfect flower, says the author, form several depressed, equally-divided whorls, and may be connected either by one or two spiral lines which run parallel. Hence we must distinguish uni- and bi-spiral flowers. The organic spirals of Dicotyledonous flowers consist typically of five-membered, bi-spiral whorls; but there are uni-spiral flowers. These usually consist of three whorls; the sepals form the first whorl, the stamens the second, and the pistil the third. These are the only true apetalous flowers, the other apetalous flowers which occur being readily distinguishable by the number and position of the stamens; to these the Thymeleaceæ, Polygonaceæ, &c. belong. The flowers of Monocotyledons are distinguished from those of the bi-spiral Dicotyledons, merely by the three-membered whorl, and thus, like the latter, they also present a calyx and a corolla; hence it is incorrect to ascribe to them a perigone. I shall merely remark here, that this

expression emanates from Ehrhart, and signifies the presence of both calyx and a corolla. The word is well constructed. *P. externum* signifies the calyx, *P. internum* the corolla; hence the expression may be conveniently used where an intermediate form is present, as in many of the Monocotyledons, especially, however, in the Thymeleaceæ, the Polygonaceæ, &c., for the true calyx of a *Chenopodium* is very different in structure from the calyx of the corolla of a *Daphne*.

Disquisition upon a Problem propounded in Phyllotaxy. By ANTON. PRESTRANDREA. Messina, 1843. A. M. Argentano presented for solution, in a journal (Interprete Ann., iv, No. 7), a problem in the theory of the arrangement of leaves, and it is very satisfactory to find that this German theory has travelled as far as Sicily; which would certainly not have been the case, if the excellent report of Martius and Bravais had not appeared in the 'Annales des Sciences Naturelles.' The problem is as follows: In a plant, the arrangement of the leaves of which is spiral, the spiral winds 13 times around the stem, and the angle of divergence amounts to $137\frac{11}{17}$ degrees; to find the number of leaves or foliar organs which compose the cycle. The solution is very simple. If we denote the angle of divergence by d, the number of turns by a, the number of foliar organs in the cycle by m, we have, according to Schimper, $d = \frac{360^\circ . a}{m}$, in which we may denote one of the three magnitudes an unknown x. We then have $137 + \frac{11}{17} = \frac{360^\circ \cdot 13}{x}$, whence $(137 + \frac{11}{17})\, x = 360^\circ \cdot 13$, and therefore $x = 34$. The object is to bring Schimper's theory under consideration (although Al. Braun only is mentioned), in which the divergence of the generating spiral is assumed as $137\frac{11}{17}$ degrees, according to Bravais. The author comments at some length upon the aid which one science can afford another; as an instance

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Digitized with financial assistance from the
Government of Maharashtra
on 13 February, 2016